Effect of urban walking environment on upper body control and illness behaviour in patients with balance problems

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ABSTRACT

This thesis attempts to investigate the effect of an urban walking environment on postural control, using tri-axial accelerometers, while walking in healthy individuals and individuals with vestibular disorders or stroke. This thesis also investigates illness behaviour, using illness behaviour questionnaire (IBQ) in individuals with vestibular disorder or vestibular migraine.

The first two studies (Chapter 2 and Chapter 3) of the current thesis explored the effectiveness of use of accelerometers in measuring upper body stability control when walking in real urban environment for healthy individuals and individuals with a vestibular disorder or stroke. The findings of the current study showed that accelerometers can be used to measure gait and balance impairment particularly in outdoor settings i.e. urban walking environment. The findings demonstrated that accelerometers were able to differentiate the postural strategies utilised by people with a vestibular disorder or stroke compared to healthy controls. More specifically, both patient groups employed compensatory mechanisms including reduced walking speed and reduced trunk accelerations in order to maintain postural stability during gait in urban environments. However, greater AP head accelerations were noted in patients with stroke, indicating that stroke patients have difficulties stabilizing their head in space during walk in urban environment. In addition, mobilising on uneven surfaces had greatest effect and induced head instability particularly in ML direction in patients with vestibular disorders and in the AP direction (the direction of progression) in patients with stroke. These results indicate that

walking in an urban environment provides challenges to postural stability control in people with vestibular disorders or stroke.

The final study (Chapter 4) of the thesis investigated the pattern of illness behaviour by using illness behaviour questionnaire (IBQ) in patients with vestibular impairment including vestibular migraine. Findings of this study showed that the IBQ can be used to differentiate illness behaviour patterns between patients with vestibular disorders including vestibular migraine and healthy controls. Patients with vestibular migraine show a significantly greater fear concern about their health status, disease conviction, dysphoria and irritability which suggested the global aspects of abnormal illness behaviour. In addition greater anxiety and depression level were also noted in people with migraine.

Overall, the three studies in the current thesis present novel findings and open up to further exciting areas of research aiming at intervention options for patients with vestibular disorders, vestibular migraine or stroke. Investigation of patient's functional mobility in real environment and the examination of patient's illness behaviour associated with their vestibular impairment may provide a critical way to identify and better understand factors that could hinder some individuals from responding well to their interventions.

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LIST OF ABBREVIATION

TUG	=	Timed Up and Go
FGA	=	Functional gait assessment
ADL	=	Activities of daily living scale
VADL	=	Vestibular disorders activities of daily living scale
VADL-F	=	VADL-Functional
VADL-A	=	VADL-Ambulation
VADL-I	=	VADL-Instrumental
VSS	=	Vertigo symptoms scale
VSS-V	=	VSS-Global vestibular
VSS-A	=	VSS-Somatic anxiety
HAD	=	Hospital anxiety and depression scale
HAD-A	=	HAD-Anxiety scale
HAD-D	=	HAD- Depression scale
ABC	=	Activities Specific Balance Confidence Scale
RMS	=	Root mean square
nRMS	=	Normalised root mean square acceleration
SVQ	=	Situational vertigo questionnaire

SE	=	Standard error
SED	=	Standard error difference
SD	=	Standard deviation
CP	=	Canal paresis
DP	=	Directional preponderance
ML	=	Medio-lateral
AP	=	Antero-posterior
V	=	Vertical
VOR	=	Vestibular ocular reflex
uVL	=	Unilateral vestibular lesion
FMA	=	Fugyl-Meyer Assessment

CHAPTER 1 GENERAL INTRODUCTION

1.1 Overview of adult human locomotion

Human locomotion has been described as an ability of a person to move from one place to another and manifests in many ways including walking, running or jumping. Walking provides the basic foundation of independent mobility in most activities of daily living (ADL) in humans and 'gait' is the term used to describe a particular manner or style of walking. Understanding of the basic mechanism and requirement for successful gait are essential to identify any potential threat such as fall during gait.

The human gait cycle, defined as a single sequence function of one limb, consists of the stance and swing phases. Stance phase is the time during which the limb is in contact with the ground, while the swing phase denotes the time when the same limb lifts off the ground and swing forward towards the anticipated landing position. This cyclic movement pattern is repeated over and over with an assumption that successive cycles are all about the same. During the stance phase, the supporting limb is in a state of receiving body weight (weight acceptance) as the person's body weight immediately transfers onto the limb as soon as the opposite limb moves forward in the direction of progression (Kirtley, 2006). During the swing phase, the same supporting limb is lifted off the ground and swing forward to the anticipated landing surface. It begins immediately after toe-off and ends once the foot touch the ground again (heel contact). At the end of the swing phase, the foot is positioned for weight bearing and muscles stabilize the body to absorb shock of heel contact (Kirtley, 2006).

At heel contact the swing phase ends and a new gait cycle begins. An adult's typical gait cycle consists of 60% stance and 40 % swing phase (Perry, 1992) however the phase proportions change as walking speed increases or decrease (Andriacchi et al., 1977).

Approximately two-third of a person's total body mass is located in the head-arms-trunk (HAT) segment. During gait HAT mass progresses in a hypothetical line of progression and is balanced over the moving lower limbs. This causes the body's centre of gravity to frequently be located outside the base of support (feet) thus introducing a continuous state of imbalance during gait (Jian et al., 1993, Lugade et al., 2011). The ability of one's body to effectively balance the HAT mass over the lower extremities through coordination of joints and body segments motion specifically within pelvic, knee and ankle, provides smooth forward progression of the CoM and postural control during gait (Kepple et al., 1997).

A systematic and synchronised interaction between various systems and subsystems is crucial for successful gait where goal-directed continuous movement and maintenance of balance (postural control) needs to be executed simultaneously. This could be achieved through a contribution from both neurological and non-neurological aspects. Neurological aspects include the central pattern generator (CPG), descending motor pathway, sensory feedback and cognitive system (MacKay-Lyons, 2002, Takakusaki et al., 2008, Jahn and Zwergal, 2010, Woollacott and Shumway-Cook, 2002, Yang and Gorassini, 2006, Nielsen, 2003), whereas non-neural aspects are musculoskeletal and environmental contributions (Shumway-Cook et al., 2002, Fraix, 2012, Sadeghi et al., 2000). Interruption to these systems due to pathology or aging could

affect the dynamic stability and functional gait (Dietz, 2002, Jonkers et al., 2009, Schrager et al., 2008, Lamontagne et al., 2007b, Shkuratova et al., 2004)

1.2 Requirements for successful gait

1.2.1 Rhythmic patterns of gait

The existence of neural networks in the spinal cord producing rhythmic movements such as walking, hopping and swimming, even when isolated from brain and sensory inputs, have been widely observed in animals (Rossignol, 1996, MacKay-Lyons, 2002). These specialised neural circuits known as central pattern generators (CPG) and the existence of CPG in human spinal cord was also noted (MacKay-Lyons, 2002). A study using electrical stimulation of the posterior structures of the second lumbar segment in complete paraplegics elicited locomotor-like EMG and flexor movement in the lower limbs, this finding suggests that human spinal circuitry is capable to generate locomotor-like activity even in the absence of input from brain (Dimitrijevic et al., 1998).

Although CPG is capable of generating a rhythmic gait pattern, input from supraspinal levels and sensory systems are important for effective locomotor behaviour. Sensory afferents involved in muscle and cutaneous reflexes have important regulatory functions in preserving balance and ensuring stable phase transitions in the locomotor cycle (Rossignol et al., 2006). Supraspinal inputs are important in initiating locomotion and in adapting gait patterns in response to environmental perturbations (Yang and Gorassini, 2006, Nielsen, 2003).

1.2.2 Postural control

Postural control refers to the ability to maintain body stability and orientation in space (Horak, 2006). Postural orientation is an ability to maintain appropriate

alignment between body segments and appropriate relationship between the body and the environment. While postural stability is an ability to control the body's centre of gravity in relation to the base of support (Horak, 2006). Postural control is a complex motor skill derived from multiple sensorimotor integration (Peterka, 2002).

Gait would introduce greater challenges to the postural control system compared to quiet stance because postural stability needs to be continuously and accurately adjusted according to environmental changes and task demands (Winter, 1995, Pozzo et al., 1995).

Sensory information from vestibular, somatosensory and visual system must be integrated to interpret complex sensory environments and to provide information about head and body orientation in relation to gravity or space. Musculoskeletal component provides appropriate posture alignment, adequate joint range of movement and muscle tone. Ideal alignment during stance alignment allow minimal muscular effort to maintain the upright position. Adequate muscle strength is important to generate sufficient muscle force to counteract the force of gravity while loss of joint range movement can limit the ways in which a person can move for postural control (Shumway-Cook and Woollacott, 2007).

Healthy person should be able to use three different movement strategies to recover from postural instability due to perturbations (Horak et al., 1997). When a person is exposed to a slow and small amount of sway, an ankle strategy is used in which the body moves primarily at the ankle as a flexible inverted pendulum. A hip strategy is used when a person is exposed to a larger and faster perturbations in which ankle rotational forces are insufficient to maintain postural stability (Buchanan and Horak, 1999). When both ankle and hip

strategies not sufficiently recover stability, step is taken to prevent body from falling. Taking a step to recover imbalance is common during gait in which the centre of gravity commonly moved forward beyond the body limit of stability.

1.2.3 Adaptation according to task and environment

One of requirement of successful locomotion is the ability to adapt gait to a wide-range of environmental conditions. The central nervous system (CNS) must continuously anticipate and counteract any destabilising forces result from the locomotion activity. For example, when a person walk from a level onto inclined walking surface (such as a ramp), limb trajectory and body posture need to be modified to ensure safe toe clearance and foot placement as the elevation and orientation of the support surface changes. Inappropriate body segments movement can adversely affect dynamic stability (Prentice et al., 2004).

Central nervous system uses information from sensory systems to detect any destabilising forces such as a slip or a trip, and trigger stabilizing reactions (reactive strategies) and also proactively modify gait patterns in advance to avoid obstacles that threaten balance (Marigold and Patla, 2005). Prior experience with a perturbation helps subsequent modification of postural responses and allow safe locomotion in complex environmental condition (Marigold and Patla, 2002).

Shumway-Cook and colleagues (2003, 2002) highlighted the effect of environment on functional limitation. In these studies, the authors suggest that physical environment dimensions such as terrain, ambient conditions (light and weather conditions), distance etc. play a significant role in mediating the relationship between functional limitations related to walking and the

development of mobility disability. An ability to dynamically re-weigh sensory inputs relative to environmental changes, is important for postural stability control (Horak and Macpherson, 2010), for example when a person moves from a well-lit to a dimly lit sidewalk. Previous studies have demonstrated relative contributions of sensory systems under altered sensory environment on postural control in healthy individuals (Peterka and Loughlin, 2004, Oie et al., 2002, Kuo et al., 1998). Sensory reweighting has been shown reduced due to ageing, sensory system and CNS impairment (i.e. stroke, Parkinson's Disease) (Peterka and Black, 1990, Woollacott et al., 1986).

Although studies have demonstrated the importance of gait adaptability to task and environmental demands, most of the studies have focused on gait analysis in a well-controlled indoor setting (Pozzo et al., 1995; Horak and Macpherson, 2010, Marigold and Patla, 2002). The indoor setting may not reflect to the true picture of difficulty faced by patients when they are navigating in real environment where constant adjustment to postural stability control is required when walking in a crowd, crossing obstacles and road, avoid bumping into people and scanning environment for navigational and safety purpose.

Standard clinical outcome measures for example functional walk tests, are commonly conducted in a well-controlled indoor setting and the outcomes mainly focus on walking speed and distance covered during gait in which commonly short distance walked in indoor setting (Iosa et al., 2012c, Eng et al., 2002). However this is different from being able to navigate complex environments which usually involves longer walking distance and requires gait adaptation according to environmental (walking on cobbled pathway vs. level ground) and task demands (carrying a shopping bag). This requirement is

crucial for community ambulation particularly in patients with sensory or CNS impairment (Lord et al., 2006).

1.2.4 Cognitive factors

There is considerable evidence of cognitive function contribution to the regulation of gait and postural stability particularly in older adults (Alexander and Hausdorff, 2008, Woollacott and Shumway-Cook, 2002, Yogev-Seligmann et al., 2008). Safe ambulation may require a specific cognitive contribution e.g. executive function (EF) and reduced cognitive function has been shown to be associated with increased gait instability and risk of falls (Montero-Odasso et al., 2012, Yogev-Seligmann et al., 2008, Mirelman et al., 2012). Executive function consists of a set of high-level cognitive domains (e.g. cognitive flexibility, inhibition control, problem solving, planning) that are necessary to plan, initiate, execute, and monitor goal-directed behaviour through regulation of basic cognitive abilities and attentional resources (Yogev-Seligman et al., 2008).

Walking in an everyday environment (i.e. local high street) which is often complex requires a person to pay attention to various environmental features and potential threats to postural perturbation. A person may continually needs to adapt his/her gait patterns in negotiating obstacles, change progression direction or re-plan a navigation path (Frank and Patla, 2003). Moreover, a person may require to execute additional task concurrently e.g. walk and talk, walk and reading a sign board. Ability to divide attention between tasks and give prioritisation to the more important task (commonly referred as the posture first strategy) is important, particularly in public where the ability to negotiate

competing/interfering demands from environment are dominant. Appropriate prioritization helps to prevent loss of balance (Shumway-Cook et al., 1997). Reduced gait speed is commonly observed in healthy adults when they are required to perform a secondary task (Yogev-Seligmann et al., 2008, Woollacott and Shumway-Cook, 2002). The effects of divided attention are more evident in condition where a locomotor task is challenged (i.e. obstacle course) (Weerdesteyn et al., 2003) and/or in other population e.g. patients population (Bessot et al., 2012, Yogev-Seligmann et al., 2008) or older adults (Harley et al., 2009, Dubost et al., 2006). Study has also shown that higher cognitive function i.e. cognitive shifting and flexibility contribute significantly in curve path navigation which further support increased cognitive demands during complex gait (Lowry et al., 2012).

1.3 Gait impairments

Gait is a critical component of many activities of daily living that are necessary for independent life. Some studies have identified functional status including self-care, mobility, and the capacity to perform various family and work roles as predictor of decrement in health related quality of life (HRQOL) in patients with gait impairment e.g. stroke, Parkinson Disease (Ellis et al., 2011, Marras et al., 2008, Carod-Artal et al., 2000). Particularly, functional assessment items related to postural instability and gait limitation appears to have a strong relationship with HRQOL (Ellis et al., 2011, Marras et al., 2008).

Impairments of the spatio-temporal, kinetic and/or kinematic aspects of gait commonly occur as a result of damage to the sensory, nervous, and/or musculoskeletal systems. The following sections will discuss the effect of these

factors on gait. Understanding the contribution of these elements to gait abnormality may lead to a better treatment and management of patients with gait impairment.

1.3.1 Effect of motor impairment on gait

1.3.1.1 Musculoskeletal factor

Lower extremity muscle weakness, reduce range of joint motion or change in skeletal alignment could affect gait and postural stability. Lower limb muscles including ankle plantar flexors (gastrocnemius, and soleus), hip and knee extensors, rectus femoris as well as hamstrings provide vertical support and forward propulsion of trunk, contribute to leg swing initiation and power generation during unimpaired gait cycle (Liu et al., 2008, McGowan et al., 2008, Hall et al., 2011, Neptune et al., 2001). The muscles contribution generally increase with increasing gait speed (Liu et al., 2008). Deficit in lower limb muscles that contribute in forward propulsion, leg swing initiation and power generation due to pathology (e.g. stroke) is directly associated with reduced functional walking status (Hall et al., 2011). Musculoskeletal limitations found in person with neurologic dysfunction (e.g. stroke) most often develop secondary to a central nervous system lesion and restricted movement.

Muscles generate forces that are transmitted by bones and connective tissue to other body segments, causing the foot to apply a force to the ground (Zajac et al., 2002). The ground applies a reaction force that is equal in magnitude and opposite in direction to each foot, which accelerates the centre of gravity forward (i.e. propulsion), backward (i.e. braking) and vertical (i.e. support) (Winter, 1995). This external force known as ground reaction force (GRF) passes upward from the foot and produces movement at each lower extremity

joint (Winter, 1995). To maintain postural stability, the GRF must be exactly balanced by the internal force produced by lower limb muscles particularly at the ankle (Kirtley, 2006). Asymmetrical generation of propulsion GRF between two feet can therefore lead to asymmetrical gait in patients with stroke (Balasubramanian et al., 2007).

Body alignment refers to the relationship of individual body segments to each other and also the position of the body in relation to gravity and base of support (Shumway-Cook and Woollacott, 2007). Correct body alignment allows execution of movement strategies that will be effective for posture control. Changes in body alignment could be due to musculoskeletal impairment or as a postural compensation secondary to other impairment e.g. patients with stroke (Shumway-Cook and Woollacott, 2007). For the later reason, asymmetry postural alignment during upright stance could be observed in a person with stroke due body weight shifted to non-paretic side (weight bearing asymmetry (WBA) (Genthon et al., 2008). The WBA could be attributable from motor weakness on the paretic side, asymmetry muscle tone, somatosensory deficit and alteration in spatial cognition with reference to the postural body scheme following stroke (Genthon et al., 2008, Barra et al., 2009, Pérennou, 2005, Roerdink et al., 2009). A study has shown significant association between WBA and functional ambulation in chronic stroke whereby reduced WBA associated with a better functional ambulation (Adegoke et al., 2012).

Musculoskeletal problems can reduce range of joint motion and flexibility thus will limit the ways a person can move to maintain dynamic stability. For example, loss of an ankle range of movement will limit a person to use ankle strategy for postural control (Horak and Nashner, 1986). Reduced range of joint

motion of lower limbs has been shown associated with altered spatio-temporal gait parameters i.e. reduced gait speed, stride length and also decrease foot elevation angle during gait particularly at toe-off (Laroche et al., 2006, Laroche et al., 2007). Failure to properly clear foot from ground or obstacle during gait could possible lead to a tip and subsequently fall (Said et al., 1999).

1.3.1.2 Neuromuscular factor

In human gait, the neuromuscular system contributes in re-directing the centre of gravity forward and over the support limb during step-to-step transition of the gait cycle. Neuromuscular control is required to reduce the metabolic cost of walking and is important for modulating walking speed, particularly in older adults (Kuo et al., 2005, Clark et al., 2013). A study by Clark et al. (2013) showed that maximum walking speed in healthy, well functioning older adults is limited by impaired neuromuscular activation and force production of triceps surae muscle group. Previously, walking speed has been shown highly dependent on neuromuscular function of the triceps surae muscles (Liu et al., 2008).

Precise control of dynamic stability of the ankle joint particularly at the terminal swing phase is essential during normal gait (Tropp, 2002). During the swing phase, a process of neuromuscular preparation for the subsequent weight-bearing stage of the gait cycle is important to ankle stability and inappropriate positioning of the lower limb before heel strike would appear to increase the potential for hyperinversion injury (Troop, 2002). A study has shown increased activation of peroneal muscles, which plays an integral role in controlling the amount of inversion occurring at the ankle joint, during the terminal swing phase

in subjects with functional instability of the ankle joint (Delahunt et al., 2006). The authors suggest increased the muscle activation may serve as a protective mechanism to prevent ankle sprain.

Walking on unstable terrain (i.e. changes in surface compliance) can disturb normal movement dynamics and strategies to accommodate such disturbances must be readily available. Neuromuscular systems is important in producing recovery response of limbs to a compliant-surface perturbation e.g. stepping on a compliant surface (Marigold and Patla, 2005) to ensure dynamic stability is still preserved. The central nervous system actively modulated muscles activity throughout the recovery response particularly during stepping off the compliant surface (Marigold and Patla, 2005).

Mobility tasks often require rapid alterations of muscle activation, and a slower neuromuscular activation rate may pose a particular challenge when task demands are high such as fast walking, stair negotiation, and balance recovery after tripping (Schmitz et al., 2009, Larsen et al., 2008, Madigan, 2006). It is suggested that impaired neuromuscular activation rate may limit mobility function by compromising the ability to produce acceleration and power at joints of the lower extremities particularly during tasks that require rapid movement or high levels of effort (Clark et al., 2011).

1.3.2 Effect of sensory impairment on gait

1.3.2.1 Somatosensory

Somatosensory receptors including muscles spindle, Golgi tendon organs, joint receptors and cutaneous mechanoreceptors provide information about joint

position in space and the position and movement of body in relation to the support surface. Loss of somatosensory information from the lower limbs resulting from experimental manipulation is known to result in increased postural sway and altered postural control (Diener et al., 1984, Horak et al., 1990).

Role of somatosensory input during gait, can be investigated by using mechanical vibration. Mechanical vibration to muscle or tendon can selectively activate the Ia afferent, which is a primary proprioceptive receptor (Inglis et al., 1991). When mechanical vibration was applied to the lower limb muscles of healthy adults during walking, it elicited changes in walking velocity, muscle activation patterns, or joint kinematics (Ivanenko et al., 2000, Verschueren et al., 2002, Verschueren et al., 2003). Findings of these studies suggest that the proprioceptive input from muscle spindles important for maintaining the steady state of human gait, contribute to the regulation of gait phase and the Ia input is used in the online control of local joint displacement during gait. It is also suggested that proprioceptive information from lower limb muscles may convey information about the velocity of the foot relative to the trunk (Ivanenko et al., 2000).

1.3.2.2 Vision

Vision improves upright stability during standing and gait by providing information about self-motion and posture and movement of body segments relative to surrounding environments and can also influence the postural alignment with reference to gravity and the environment during gait. Vision also provides support in gait cycle modulation, provides environmental information at

a distance thus support navigation and obstacle avoidance during gait (McFadyen et al., 2007, Schubert et al., 2003, Rossignol, 1996). Obstacle information provided by vision can control mode of gait regulation through a feed-forward mechanism. Specifically, visual information is used to alter gait patterns in anticipation of upcoming obstacles (Patla and Vickers, 1997). During navigation, for example around obstacle in a cluttered terrain, visual information provides information about the obstacle and identification of safe corridors. This information thus help a person in path planning (Patla et al., 2004).The role of vision to modify gait patterns in response to environmental constraint has been reviewed extensively and it has been suggested that integration of visually perceive the environmental properties at a distance and modify the movement patterns in an anticipatory manner is crucial to ensure dynamic stability during adaptive locomotion (Higuchi, 2013).

Studies have shown that optic flow has a modulating effect on gait patterns i.e. speed and stride length (Konczak, 1994, Prokop et al., 1997). These findings suggest that imposed optic flow has a modulating effect on gait patterns wherein global backward and forward optic flow tended to decreased and increased gait speed respectively (Konzack, 1994, Prokop et. al., 1997), changes observed in the gait speed was closely related to a modulation of step length (Prokop et al., 1997).

Aforementioned studies have shown the importance of visual input to feed-forward control of equilibrium during gait, gait regulation, navigation and obstacles avoidance. Therefore loss of vision may affect the stability and adaptation aspects of gait as well as route finding and obstacle avoidance.

1.3.2.3 Vestibular

The role of the vestibular system is to contribute to gaze and posture stabilization as well as sensation of orientation and movement. Human vestibular system is made up of three components: a peripheral sensory apparatus, a central processor, and a mechanism for motor output (Hain and Helminski, 2000). The peripheral apparatus includes the three semicircular canals (horizontal, anterior, posterior SCC) and the otoliths (utricle and saccule) and they are responsible for detecting and providing information about angular head velocity, linear acceleration and static head tilt with respect to the vertical axis (gravity). The CNS processes these signals and integrates them with other sensory information to estimate head and body orientation in space.

The reflexes involving the vestibular system include the vestibule-ocular (VOR), the vestibulo-cervical (VCR), and vestibule-spinal reflexes (VSR). The VOR produces and maintains conjugate eye movement that is synchronised with the velocity of head motion to generate stable fixation of the eyes on an object during head movement (Hain and Helminski, 2000). The VSR and VCR allow input from the vestibular organs to be used for the body postural orientation in gravity environment and help stabilize head and body in space (Hain and Helminski, 2000, Buchanan and Horak, 2001). Vestibular input is essential for postural orientation when both visual and somatosensory are inadequate to control centre of gravity over the base of support such as standing in the dark on an uneven surface (Horak, 2010).

It is well documented that vestibular disorders result in postural instability (Pozzo et al., 1991, Allum et al., 2001), impaired gaze stability (Whitney et al, 2009, Hillman et al., 1999), change in gait patterns (Cohen, 2000, Borel et al.,

2004, Marchetti et al., 2008) and an increased falls risks (Whitney et al., 2004a). Patients with a peripheral vestibular disorder show significant changes in their walking pattern compared to healthy individuals including a wide base of support, reduced walking speed and step length, and deviations from the walking path (Cohen, 2000, Borel et al., 2004, Marchetti et al., 2008). These changes are particularly evident when patients are walking with head movements, at a fast speed, or when visual input is unavailable (Borel et al., 2004, Cohen, 2000, Nascimbeni et al., 2010).

The head is relatively stable during many walking tasks (Pozzo et al., 1990). However voluntary head movements are common during activities of daily living involving both walking and standing. Examples include looking side to side to cross the street, turning the head in response to an auditory signal, and navigating through a visually challenging and busy environment e.g. a supermarket, shopping centre or train station. These movements are necessary in order to scan the environment and obtain information regarding surrounding objects and our proximity to them. These typical everyday dynamic movements exacerbate symptoms of dizziness and unsteadiness as well as blurry vision in patients with a vestibular disorder and it is understandable that these difficulties can lead to activity limitations and contribute to a decreased quality of life. It has been suggested that a phenomenon referred to as visual vertigo (Bronstein, 2004) or space and motion discomfort (Jacob et al., 1993), may be a contributing factor to the difficulties experienced by patients particularly during gait in challenging environments.

1.4 Current approaches to balance and gait assessments

1.4.1 Functional assessments

Functional balance assessment tools rate performance of various tasks challenging balance control in order to identify functional limitations to do a task or an activity and it also provide information about balance status and its changes with time (Horak, 1997).

The Time Up and Go test (TUG) is widely used as clinical balance test because it is quick, easy and convenient to be performed in the clinic (Yelnik and Bonan, 2008). It provides information about the time required for a person to rise from a chair, walk 3 meters, turning and returning to the start point. It has been used to assess mobility performance in older adults and to assess risk of falls (Shumway-Cook et al., 2000, Podsiadlo and Richardson, 1991). Its scores relate to risk of falls in older adults and in patients with a peripheral vestibular disorder (Shumway-Cook et al., 2000, Whitney et al., 2004a). Although TUG involves several important mobility skills that challenged postural control such as sit-to-stand and turning, it is not able to separate which balance and gait components are affected.

The Functional Gait Assessment (FGA) is an ambulation-based balance test specially developed for patients with vestibular disorders (Wrisley et al., 2004). It was derived from Dynamic Gait Index (DGI), which was validated in various populations yet had a potential ceiling effect (Jonsdottir and Cattaneo, 2007, Wrisley et al., 2004). The FGA eliminated the ceiling effect noted in DGI when the test was used in patients with a vestibular disorder (Wrisley et al., 2004). It consists of 10 tasks and includes tasks such as walking with head movements, tandem, or backwards. It has been shown easy to administer in most clinical

setting (Wrisley et al., 2004). The FGA has shown to be a reliable tool with intra-rater and inter-rater reliability reported as r=0.86 and r= 0.75 respectively (Wrisley et al., 2004). For adults up to the age of 60 years, the normal score on the FGA would be considered >27/30 (Walker et al., 2007). The cut off of 22 points predictive of falls in older adults (Wrisley and Kumar, 2010).

1.4.2 Objective assessments

1.4.2.1 Computerised dynamic posturography

The Sensory Organization Test (SOT) allows systematic evaluation of sensory contribution to balance control via manipulation of either visual or support surface or both. The testing is performed under six different sensory conditions to assess the influence of visual, vestibular and somatosensory inputs on balance. In conditions 1 to 3 subjects stand on a stationary support surface with eyes open, eyes closed, and with sway-referenced vision, respectively. In conditions 4 to 6 a similar procedure is followed except the support surface is also sway referenced. The program yields an average composite equilibrium score, ranging from 0 % (no balance) to 100% (maximum stability). Scores below 70% are considered abnormal (Neurocom, 1999). Although the system could provide accurate information about dynamic postural control during standing, it does not provide information about dynamic postural control during gait. It also requires time for both training and testing, space for the storage and high cost (Visser et al., 2008).

1.4.2.2 Gait analysis systems (non-wearable sensors)

Standard gait analysis systems can be classified into image processing based system, floor sensors (force platforms or instrumented walkway) or dynamic

electromyography (EMG). The image processing system (camera or optic sensors camera) provides information about the magnitude, timing and phasic relationships of a person's gait. The floor sensors system allows measurement of force exerted by a person's feet on the floor during walking thus provides information about the kinetics aspect influencing gait. Overall, these systems provide biomechanical measures of kinematic, kinetics, muscular activity that are essential for a complete picture of specific gait characteristics (Coutts, 1994).

Study has demonstrated the validity of these systems to quantify and analyse different aspects of human gait (Muro-de-la-Herran et al., 2014). These systems would provide comprehensive outcomes due to its high accuracy of analysis in detecting more specific gait parameters. Other advantages of these gait analysis system are that they could isolate external factors from influencing the measurements and allow more controlled analysis on data being studied. Thus resulting in high repeatability and reproducibility levels.

Typically standard gait analysis session in patients with disability e.g. stroke involves a few short successive recording gait trials for a person (Kim and Eng, 2004). However previous evidence demonstrated that gait performance during community ambulation among stroke survivors were influenced by several factors including fatigue (poor endurance) (Eng et al., 2002), reduce ability to adapt to environmental task demands (Said et al., 1999, Lord et al., 2006). These factors are not taken into account in the system data interpretation. Other disadvantages includes high cost (expensive) due to the needs for the setting up in a specialised gait laboratory, took longer for set up and it requires post-processing times. For the floor sensors set up, the instrumented walkway size

(the length of a mat sensor) would limit the data collection from a person. In addition, these systems do not allow evaluation and monitoring of patient's gait while conducting activity of daily living outside the laboratory setting. Thus extrapolating the study findings outside a well-controlled laboratory studies may not reflect the patient's actual performance.

To alleviate the limitation of the standard gait analysis based on the non wearable system, an alternative method based on wearable sensors was studied. This alternative system allow gait analysis in outdoor setting and can provide information about gait characteristics while a person is conducting activity of daily living in real environment (Muro-de-la-Herran et al., 2014)

1.4.2.3 Accelerometers

Accelerometers are wearable motion sensors that can be used to examine human body segmental accelerations in up to three planes (anterior–posterior, mediolateral and vertical). Accelerometers have been shown to be a valid and reliable tool to measure dynamic movements and are able to provide an objective measurement of postural stability control during walking (Mayagoitia et al., 2002, Kavanagh et al., 2006). It has been tested for accuracy (Moe-Nilssen, 1998) and for test-retest reliability during standing and walking. By using single triaxial accelerometer at L3 spinous region, the intraclass correlation coefficient (ICC) ranged from 0.79 to 0.94 when considering the vertical (V), anterior-posterior (AP) and medio-lateral (ML) acceleration axes as well as walking on even and uneven surface. Reliability was on the similar level for even and uneven walking surface. Good reliability evidenced from multiple accelerometers attached to different segments of the upper body (head, C7 and

L3 of spinous region and shank) (Menz et al., 2003b, Kavanagh et al., 2006) prove that the accelerometers are valid tools for measuring dynamic movement.

Accelerometers can accurately measure simple parameters of gait e.g. stride time, stride symmetry and speed (Kavanagh and Menz, 2008b, Kavanagh et al., 2004, Menz et al., 2003c, Moe-Nilssen and Helbostad, 2004). Repeated patterns obtained with measures of acceleration contain information on the smoothness or variability of the walking pattern particularly trunk accelerations (Kavanagh and Menz, 2008b, Kavanagh et al., 2004, Menz et al., 2003c). It can also quantify gait pattern in healthy and person with balance or gait problems e.g. elderly, stroke, Parkinson disease, multiple sclerosis (Menz et al., 2003c, Menz et al., 2003a, Huisinga et al., 2012, Latt et al., 2009, Iosa et al., 2012b). In previous studies, head and/or pelvic accelerations were observed to be significantly less stable in healthy older adult compared to young adults (Menz et al., 2003c), in older people with a high risk of falls compared to those at a low risk (Menz et al.,2003a), and in people with stroke (Iosa et al., 2012b, Mizuike et al., 2009). Moreover, accelerometers have also been used to examine the effects of ageing on head and trunk movements while walking on level or irregular surfaces (Menz et al., 2003b). Aforementioned studies suggest that accelerometry data could provide useful indicators of gait stability.

1.4.3 Potential use of accelerometers to measure complex task in real walking environments.

Causes of falling are multifactorial, however, impairment in gait and balance are often fundamental (Tinetti et al., 1988). Ambulation in real environment which require a person walk at faster speed and a longer distance was noted to further

increase the risk of fall among high risk faller population (Shumway-Cook et al., 2002, Lord et al., 2004). Identification of these gait abnormalities is essential to early initiation of appropriate therapeutic intervention as part of a falls prevention strategy. Accelerometers can be used to measure these gait changes.

Accelerometers have advantages over the standard gait analysis system (non wearable system) primarily due to its small size, light weight, limited restrictions to regarding anatomical placement, and it also provides minimal obstruction to body movement. It can be used to measure movement including gait, in laboratory and real world environments without the limitations inherent to more immobile laboratory approaches such as force plate/camera systems. It also allow continuous measurement of a person's daily activities in his/her own environment (Haeuber et al., 2004). Many accelerometers are wireless and either send signals to a base station or collect data onboard for subsequent download, further promoting the usefulness of accelerometers especially in an environment with exposure to various conditions such as when ambulating within the community.

A limited number of studies have incorporated the use of accelerometers to assess free-living physical activities and mobility in the community (Hendelman et al., 2000, Haeuber et al., 2004). Haebuer and colleugues (2004) compared the accuracy and reliability of conventional accelerometers and Step Watch Activity Monitor (SAM) to quantify stride counts during two 48 hour monitoring periods in subjects with a chronic stroke. The SAM was an ankle-mounted microprocessor-linked accelerometer and allow recording of gait cycle, or stride human. However the conventional accelerometer was a hip-mounted

mechanical accelerometer. Findings revealed that both types of accelerometers were able to quantify the stride counts however SAM showed higher accuracy and reliability for quantifying ambulatory activity in stroke population (Haueber et al., 2004).

Prolonged walking in living environment is more challenging compared to short distances walked in clinic setting. Prolonged walking has been shown to affect gait dynamic stability in patients with stroke (Iosa et al., 2012c) which may potentially increase risk of fall. In the study, accelerometery data was able to distinguish gait stability patterns between patients with stroke and healthy during prolonged walked (6 minutes walking task-6 MWT) (Iosa et al., 2012c). Patients with stroke showed progressive reduction of dynamic gait stability during prolonged walk. Furthermore the accelerometer could pick up differences of gait strategies used by the patients wherein patients either maintain gait speed but showed progressive reduction of gait stability or reduced both gait speed and gait stability. Reduced both speed and stability was noted in patients with less ability to walk prolonged (Iosa et al., 2012c).

Accelerometer has been shown reliable to measure dynamic movement. It has been proposed as being suitable for fall detection in person who are at high risk of fall. It can be used continuously and provide objective assessment of mobility in a clinical and also in free-living environments.

1.5 Effects of psychological state on subjective symptoms and functional capacity

1.5.1 The relationship between psychological state, dizziness and functional ability in patients with peripheral vestibular dysfunction

Significant comorbidity between vestibular dysfunction, migraine and anxiety has been reported. Patients with a vestibular disorder, including migraine associated dizziness often have a comorbid psychiatric disorders (e.g. anxiety or depression) (Staab and Ruckenstein, 2005, Staab and Ruckenstein, 2003, Furman et al., 2005). Patients with psychiatric disorders also often experience subjective unsteadiness, dizziness or vertigo as a concomitant phenomenon of their illness (Yardley et al., 2001). The relationship between vestibular disorders and psychiatric disorders has been thought as bidirectional: a vestibular disorder may trigger a psychiatric disorder (Jacob and Furman 2001) while a psychiatric disorder may trigger symptoms of vertigo and dizziness (Yardley et al., 2001; Staab and Ruckenstein, 2003). However, some studies report no relationship between the presence of a vestibular deficit and the development of a secondary psychiatric disorder (Best et al., 2006; 2009).

A complex interaction between vestibular disorders and psychiatric disorders has been described previously (Balaban and Thayer, 2001, Yardley et al., 2001, Staab and Ruckenstein, 2003, Eckhardt-Henn et al., 2008). Based upon neuroscience evidences, the link between balance control and anxiety is suggested to be associated with neural circuits that are shared by pathways related to autonomic control, vestibular-autonomic interactions and anxiety (Balaban and Thayer, 2001). This may explain the high rates of co-existence

and co-morbidity observed clinically in patients with organic and psychiatric dizziness (Furman et al., 2005).

1.5.2 Illness behaviour and its potential influence on functional capacity

The concept of illness behaviour relates to the ways in which people attend to somatic information, interpret and respond to symptoms and seek medical care (Mechanic, 1986). Although symptoms may share similar clinical characteristics, different forms of illness behaviour may be elicited suggesting substantial inter-individual variability in a way a person responses to their symptoms (Mechanic, 1986). A term of abnormal illness behaviour (AIB) can be described as a persistent inappropriate or maladaptive mode of experiencing, perceiving, evaluating and responding to one's own health status, despite the fact that appropriate medical assessments and management have been provided (Mechanic, 1986, Pilowsky and Spence, 1994). It can also be used to describe either somatic or psychological focus and either illness is affirmed or denied (Pilowsky, 1993a).

Abnormal illness behaviour has been examined predominantly in patients with chronic pain (Pilowsky and Katsikitis, 1994, Waddell et al., 1989, Keefe et al., 1986, Prior and Bond, 2008) and psychiatric problems (Pilowsky, 1993b, Boyle and Le Déan, 2000, Guo et al., 2001, Duddu et al., 2006, Lykouras et al., 2006). Abnormal illness behaviour can be found in somatoform disorders (Chaturvedi et al., 2006), chronic pain disorders (Pilowsky and Katsikitis, 1994), psychological problems (Fava et al., 1982) and in people with diagnosed medical conditions e.g. stroke (Clark and Smith, 1997), Meniere's Disease (Savastano et al., 1996), cancer (Grassi et al., 1989). There is evidence of

increased level of illness-affirming AIB among patients with somatic symptoms or with psychological distress compared to those who were not.

Previous longitudinal studies showed that AIB could emerge during stroke rehabilitation (Clark and Smith, 1997, Clark and Smith, 1998). Proportion of patients who developed AIB during rehabilitation were doubled by the time of discharge and this remained stable at 12 months (Clark and Smith, 1997). Patients with stroke who developed AIB upon discharge also demonstrated poorer ADL ability and worse social and psychological outcomes compared to those who did not develop AIB and these discrepancies were not significant upon patient's admission to the rehabilitation (Clark and Smith, 1997). Furthermore these patients (with AIB) were consistently poorer at both 6 and 12 months post rehabilitation. It was noted that no change in illness behaviour pattern observed between patients with and without AIB at 12 months. Both depression and AIB emerged as important predictors of long-term functional disability and poorer social outcome following rehabilitation from stroke, the authors suggest that AIB may compromise the long-term functional recovery of stroke patients (Clark and Smith, 1998, Clark and Smith, 1999).

Evidence on the existence of abnormal illness behaviour in some patient populations as well as significant association between psychological state and illness behaviour on patients' ADL ability and social outcomes, may help health professionals to recognize possible underlying reasons for a patient's poor response to treatment. Abnormal illness behaviour has been shown to influence patient's manner towards seeking treatment (i.e. delay treatment) (Rizzardo et al., 1991). Improved understanding of illness pattern and AIB as well as its association with psychological disturbance could offer important insight into

early indicators of potentially maladaptive illness response. This may lead to a better planning of management strategies for patients.

1.6 Aims of the thesis

The following will provide a brief description of the purpose of each study included in this thesis. The first two studies in the current thesis (Chapter 2 & 3) were conducted to investigate postural control by using accelerometers, during walking in different urban environments in healthy participants and patient groups. Based on laboratory studies, head stability is obtained via modulation of lower trunk movement during gait cycles in healthy individual. However little is known about the head-trunk coordination while a person is walking in a real, uncontrolled environment and the effect of impaired sensory (i.e. vestibular system) or central nervous system (i.e. stroke) function on dynamic postural control in challenging walking environments. It was hypothesised that walking in real environment may reduce postural stability control among patients with sensory or CNS impairment due to reduce gait adaptability. It was expected that when patients walk through challenging environment i.e. busy or uneven surfaces, these patients would experience greater difficulty. It was also expected that healthy individuals able to maintain head stability during walking in urban environment indicating good postural stability control.

The main purpose of the first study of the current thesis (Chapter 2) was to examine the effect of a vestibular impairment on the head and trunk postural control during walking in real urban environments. The secondary aim was to correlate subjective and objective clinical outcome measures with overall

postural control strategies utilised in real environments. Outcome measures used were specific to the patients population.

Chapter 3 repeated the first study (Chapter 2) in patients with stroke. The second study focussed on the effect of CNS (i.e. stroke) damage on postural stability control. The main aim was to determine upper body stability control, by using accelerometers, when walking in urban environment for independently community-dwelling stroke survivors. The secondary aim was to determine association between acceleromtery data and functional abilities, visual dependency and subjective outcome measures in people with stroke.

The final study of the current thesis (Chapter 4) aimed to describe illness behaviour profile (the way a person responds to a perceived health threat or illness), using illness behaviour questionnaire (IBQ), in patients with chronic vestibular disorders or vestibular migraine. Secondary aim was to assess the relationship between illness behaviour, functional gait, postural control and subjective symptoms.

Overall this thesis aims to assess dynamic postural stability control in urban environments in healthy individuals and in patients with sensory or central nervous systems impairment and also the effect of illness behaviour state on patients' symptoms and functional ability.

CHAPTER 2 EFFECT OF URBAN WALKING ENVIRONMENTS ON POSTURAL CONTROL IN PATIENTS WITH A VESTIBULAR DISORDER

2.1 INTRODUCTION

Sensory input from the visual, somatosensory, and vestibular (i.e. inner ear balance system) systems play an important role in the control of walking. In urban environments the integration of sensory input from all three systems plays a significant role in a person's ability to maintain balance when walking where the movements performed must be modified in response to changes in environmental and task demands (Lord et al., 2006).

The vestibular system plays an important role in head and trunk stabilisation with respect to gravity during walking. This facilitates gaze stabilisation and provides a stable reference frame from which to generate postural responses and maintain balance (Pozzo et al., 1995, Beidel and Horak, 2001). It also contributes to navigation tasks such as walking to a previously seen target in the absence of vision (Guidetti et al., 2008).

Previous studies in patients with peripheral vestibular disorders have shown impairment in gaze stability (Hillman et al., 1999, Whitney et al., 2009), disrupted head- trunk coordination and head movement (Pozzo et al., 1991, Allum et al., 2001, Mamoto et al., 2002, Borel et al., 2002), change in spatio-temporal gait patterns (Cohen, 2000, Borel et al., 2004, Marchetti et al., 2008) and an increased fall risks (Whitney et al., 2000).

These changes are particularly evident when patients are walking with head movements, at a fast speed, when visual input is unavailable or while

completing a dual-task (cognitive) (Borel et al., 2004, Cohen, 2000, Nascimbeni et al., 2010, Glasauer et al., 1994). In addition, patients experience difficulty controlling head accelerations, and suffer from the unpleasant illusion of movement or blurring of images when walking due to impairment of the vestibular ocular reflex (VOR) (Takahashi et al., 1988, Hillman et al., 1999, Hirasaki et al., 1993, Schubert et al., 2002). The VOR produces and maintains conjugate eye movement that is synchronised with the velocity of head motion and as a result VOR generates stable gaze fixation on an object during head movement. It has been suggested that the reduced walking speed noted in this patient group helps to maintain gaze stability (Mamoto et al., 2002) and to reduce unsteadiness and falls risk (Borel et al., 2004) during walking.

The head is relatively stable during many walking tasks. However voluntary head movements are common during activities of daily living involving both walking and standing. Examples include looking side to side to cross the street, turning the head in response to an auditory signal, and navigating through a visually challenging and busy environment e.g. a supermarket, shopping centre or train station. These movements are necessary in order to scan the environment and obtain information regarding surrounding objects and our proximity to them. These typical everyday dynamic movements exacerbate symptoms of dizziness and unsteadiness as well as blurry vision in patients with a vestibular disorder and it is understandable that these difficulties can lead to activity limitations and contribute to a decreased quality of life.

It has been suggested that a phenomenon referred to as visual vertigo (Bronstein, 1995) or space and motion discomfort (Jacob et al., 1989), whereby patients become significantly more susceptible to visual motion and complain of

discomfort, symptom exacerbation and a feeling of imbalance in challenging visual environments (e.g. walking down a busy street, crossing the road and performing simple tasks such as shopping) (Kerbs et al., 1993, Tee and Chee, 2005) may be a contributing factor to the difficulties experienced by patients when walking in urban environments.

It is well documented that peripheral vestibular disorders may result in unsteadiness, particularly when walking in busy environments (i.e. crowds and supermarkets) or on uneven surfaces, and these patients have an increased falls risk (Herdman et al., 2000). Patients also show changes in walking parameters compared to healthy adults. However these studies have been conducted in highly controlled, predictable laboratory settings which are very different to walking during daily activities in an urban environment. Therefore results may not provide a true indication of the balance strategies adopted by patients with peripheral vestibular disorders in everyday life. Previous research has discussed the merits of evaluating walking and adaptations over uneven surfaces, when negotiating obstacles, and in busy places covering a variety of distances (Patla, 2001) however, it was not possible to assess these factors outside a laboratory setting because adequate techniques for use in real environments had not been established until recently.

Accelerometers, which are a wearable motion sensors, have been shown to be a valid and reliable tool to measure dynamic movements and are able to provide an objective measurement of postural stability during walking (Mayagoitia et al., 2002, Kavanagh et al., 2006). Accelerometers are able to demonstrate changes in postural stability due to different factors e.g. age, pathology etc. in various indoor walking conditions e.g. walking on ground or

uneven surfaces (Kavanagh et al., 2004, Kavanagh and Menz, 2008a, Menz et al., 2003b). It has been found to be able to distinguish between fallers and non-fallers (Menz et al., 2003a). It can be used continuously and has been proposed as a quantitative measure of balance in both clinical and in free-living environments.

No studies to date have assessed and compared postural stability control, using data from accelerometers, during walking in different urban environments. Also no studies have investigated the association between subjective reports of symptom severity, symptom triggers, balance confidence and emotional state with objective walking performance in real everyday environments. The purpose of this study was to 1) use accelerometers to assess postural control during walking in common urban environments including a colonnade with checkerboard floor pattern, a darker area, a busy section, a quiet section, and on an uneven surface (cobbled pathway) in patients with a vestibular disorder and healthy individuals and 2) investigate for associations between data obtained from the accelerometers and subjective reports of symptom severity, triggers, balance confidence and emotional state. It was hypothesised that accelerometers data can be used to differentiate gait patterns between healthy and patients and walking in challenging urban environments i.e. busy or cobbled increase postural instability, particularly in the latter. The information obtained may provide insight of the postural stability control strategies employed in real, uncontrolled environments by people with a vestibular disorder.

2.2 MATERIAL AND METHODS

2.2.1 Subjects

All participants were aged between 18 and 65 years old and independently mobile community dwelling individuals. Two participant groups were recruited:

- Patients with a diagnosed peripheral vestibular disorder (Group PV) who had never received or completed a vestibular rehabilitation programme were recruited from the Department of Neuro−otology at the National Hospital for Neurology and Neurosurgery (NHNN), Queen Square, London. All patients had completed routine audio-vestibular investigations performed by a senior audiologist prior to the recruitment. The routine audio-vestibular investigations include otoscopic examination, tympnanometry test, pure tone audiometry, bithermal caloric test (either video nystagmography (VNG) or Fitzgerald-Hallpike with optic fixation technique) and electronystagmography. Departmental norms were used for significant canal paresis and directional preponderance. A significant unilateral canal paresis was either based on Fitzgerald-Hallpike caloric testing as measured by the duration parameter using the Jongkee's formula of more than 8% in the absence of the optic fixation or ≥20% on VNG bithermal caloric. For directional preponderance, 12% for Fitzgerald-Hallpike or 20% for VNG (Jacobson et al., 1993) are the normal values. Diagnosis (or exclusion) of peripheral and/or central vestibular disorder was based upon review of the history, clinical assessment, caloric and ENG data by the attendant consultant neuro-otologist. Exclusion criteria were 1) fluctuating symptoms e.g. acute Meniere's Disease 2) Benign Paroxysmal Positional Vertigo (BPPV); 3) central vestibular disorder other than controlled

vestibular migraine and 4) a medical problems condition in the acute phase which may affect postural stability and gait e.g. orthopaedic injury.

- Healthy adults (Group C) were recruited via circular email to students and member of staff at King's College London, London, UK. The inclusion criteria were no self-reported history of vestibular or neurological disease, dizziness or any medical problems condition in the acute phase which may affect postural stability and gait e.g. orthopaedic injury.

All participants were asked to avoid consuming alcohol for 24 hours prior to testing. No participant with a vestibular disorder had taken vestibular suppressants or sedatives at least 24 hours prior the testing. Local ethics committee approval was obtained.

2.2.2 Self-report assessments

All participants completed a set of validated questionnaires prior to completing the urban walking task. For copies of all questionnaires please refer to appendixes.

a. The Situational Vertigo Questionnaire (SVQ) (Jacob et al., 1989, Guerraz et al., 2001) yields a normalized score between 0 (never) to 4 (always) measuring how frequently symptoms are provoked or exacerbated in environments with visual-vestibular conflict or intense visual motion (e.g. walking down a supermarket aisle, watching moving television scenes). Normalised scores >0.7 indicate the presence of visual vertigo symptoms (Pavlou et al., 2006; Pavlou et al.,2013).

b. The Vertigo Symptom Scale (VSS)(Yardley et al., 1992) measures the frequency of vestibular (VSS-V; e.g. vertigo, giddiness, unsteadiness) and autonomic/somatic anxiety symptoms (VSS-A; i.e. heart pounding or fluttering, excessive sweating, tingling/numbness in body part). Scores range from 0 (no symptom) to 4 (daily symptoms); Normalised scores ≥ 0.3 on the VSS-V subscale indicate a significant level of vestibular symptoms (Pavlou et al., 2006).

c. The Activities Specific Balance Confidence Scale (ABC) assesses patients' confidence in conducting activities of daily living (ADLs) such bending over, reaching for items, indoor and outdoor mobility (i.e. walking around the house, outdoors in busy places such as a mall or on uneven surface such as a ramp) without losing balance or becoming unsteady (Powell and Myers, 1995). It has been validated for use in individuals with peripheral vestibular dysfunction and demonstrates acceptable validity in this population (Whitney et al., 1999, Wrisley et al., 2004, Legters et al., 2005, Karapolat et al., 2010). Scores range from 0% (no confident) to 100% (complete confidence). Responses to individual questions are then averaged to get a percentage score, with lower scores indicating less confidence in ADL performance and scores of ≤67% indicate increased falls risk (Lajoie and Gallagher, 2004).

d. The Vestibular Activities of Daily Living Scale (VADL) (Cohen and Kimball, 2000) evaluates the impact of vertigo or balance disorders on a person's ability to carry out ADLs. The scale is separated into three domains: a) functional which relates to items associated with self-care (VADL-F; i.e. sitting or standing

up, bathing, meal preparation); b) ambulation which includes items addressing a person's ability to walk in various environments (VADL-A; i.e. narrow or crowded spaces, stair climbing) and instrumental which includes items relating to leisure activities, productivity and home management (VADL-I; i.e. carrying out light or heavy household chores, travelling on public transport). Score ranges between 0 (independent) to 10 (too difficult, no longer able to perform). The VADL demonstrated good test-retest reliability and validity (Cohen and Kimball, 2000).

e. The Hospital Anxiety and Depression Scale (HAD) (Zigmond and Snaith, 1983) independently measures anxiety (HAD-A) and depression (HAD-D) symptoms. Score range from 0 to 21 for each subscale. Score between 8-10 indicate borderline symptoms; scores ≥ 11 indicate a significant level of depression or anxiety symptoms.

2.2.3 Functional measures

2.2.3.1 Timed Up and Go (TUG)

The TUG is a simple and quick clinical test that can be used to assess functional mobility in older adultsand patients with a vestibular disorder (Whitney et al., 2004a, Gill-Body et al., 2000). The TUG is the time (seconds) required for a person to stand up from a chair, walk, at their normal speed for three meters, turn, around and walk back to the chair and sit down. In patients with a vestibular disorder, the TUG appears to be helpful in identifying fall risk (Whitney et al., 2004a). Higher (i.e. worse) TUG scores (>11.1 seconds) have

been shown to correlate with self-reported falls in this patient population (Whitney et al., 2004a). In addition TUG scores significantly correlate with self-reported disability in persons with vestibular dysfunction (Gill-Body et al., 2000).

2.2.3.2 Functional Gait Assessment (FGA)

A ten-item test, specially developed for patients with vestibular disorders, based on the Dynamic Gait Index (DGI). It includes tasks such as walking with head movements, tandem, or backwards. Each item is rated between 0 (severe impairment) and 3 (normal) with a maximum score of 30; higher scores indicate better performance. The FGA eliminated the ceiling effect noted in DGI when the test was used in patients with a vestibular disorder (Wrisley et al., 2004). The FGA has shown to be a reliable tool with intra-rater and inter-rater reliability reported as r=0.86 and r= 0.75 respectively (Wrisley et al., 2004). It also demonstrates acceptable concurrent validity with other balance outcome measures (i.e. DHI, ABC, DGI) for patients with a vestibular disorder (Marchetti et al., 2014).

2.2.4. Urban walking procedures

2.2.4.1 Instruments and preparation stage

Three triaxial accelerometers (MTx, Xsens Technologies BV; 38x53x21mm, 30g) were used to measure the acceleration and movement in pitch, roll and yaw. The accelerometers were placed at 1) the occcipital protuberance using an elastic head band; 2) over C7 and 3) over L3 respectively. Each accelerometer was affixed to the participant's skin using a hypoallergenic adhesive tape. The

accelerometers were connected to a light-weight laptop, onto which the MT Manager recording software had been installed via a data logger box. Later, both the data logger and laptop were placed in a backpack (Dimension: 34 (H) X 24 (L) X 12 (W) cm) worn by the subjects (Fig. 1A-C). The researcher ensured that normal arm movement was not affected by backpack placement before the start of the urban walking task. All participants were instructed to a) wear comfortable clothing and flat shoes, b) walk at their preferable walking speed and c) perform as they normally would in the specific environments. Two experimenters walked alongside each patient. All data were sampled at 100Hz.

Figure 1 Recording device.

Fig. 1A The recording device used for the urban walking task which consists of 3 accelerometers, data logger XBus Master, elastic head band and a notebook. Fig. 1B shows the position of the accelerometers on a participant. Fig. 1C Final view of the recording device on the participant.

2.2.4.2 Orientation of accelerometer on subject

All the accelerometers were similarly oriented with the box placed with the Y axis pointing upwards, the X axis towards the right hand side of the participant and finally the Z axis pointing anterior to posterior. The cable from each accelerometer extended towards the left hand side of the participant.

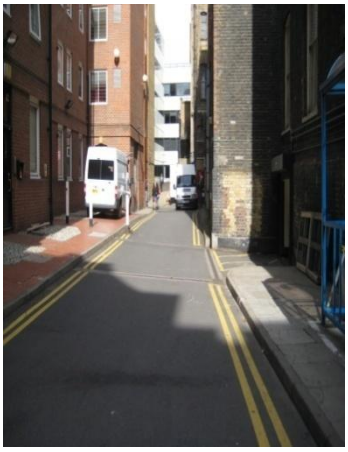
2.2.4.3 Recording stage

Once the set-up was completed, the participant was instructed to stand still with their head facing straight ahead. The alignment reset method was used to reset the local coordinate system (LCS) of each sensor corresponding to the global coordinate system (GCS) simultaneously. This type of reset method changes the Z axis of the LCS to coincide with the gravity vector (i.e. vertical). The new X axis is the projection of the old X axis onto the plane perpendicular to the new Z axis. The new Y axis is the vector mutually perpendicular to the new Z and new X axes. This new Y axis is approximately in the posterior to anterior orientation and will lie close to the line of advance during walking. The reset method was carried out only once for each participant prior to starting the walking task. In case of interruption to data recording during the walking route, the alignment reset method was carried out again before beginning to record again. The recording ended when the participant completed the walking route and return to the starting point.

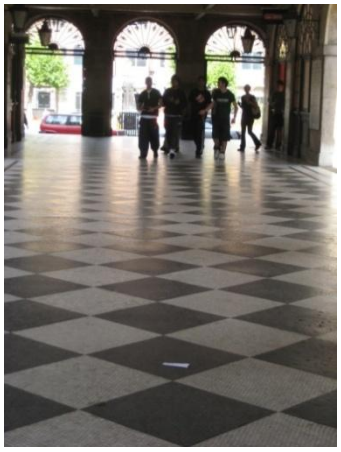
2.2.5 Walking route

The walking route distance was 1 kilometre and was separated into 54 checkpoints. Chalk crosses drawn on the road were used to identify

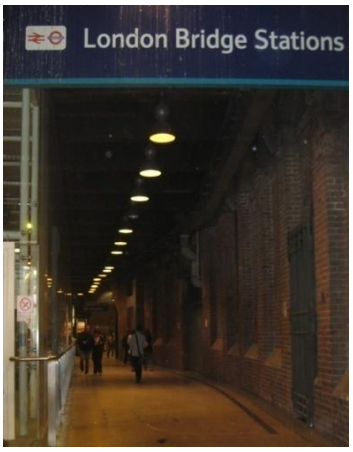
checkpoints where participants stopped and stood still for five seconds to allow for recognition of interest points during the analysis and to ensure for repeatability between subjects. Along the route, five 30 metre long sections of interest (quiet, dark, busy, cobbled street and a colonnade with a checkered patterned floor) were predetermined (Fig. 2). The route ended at the starting point.



Quiet section



Colonnade floor



Darker section

Busy section

Cobbled section

Figure 2 Photographs showing each of the 5 individual environmental conditions tested.

2.2.6 Data acquisition and processing

2.2.6.1 Extraction of raw data from MT software.

Recorded data for each subject was exported from the MT software and saved as a .txt file format. Each output file was renamed corresponding to the position of each sensor on the participant's body (e.g. output from sensor 153 was renamed to 'participant's ID'-'position'). In total, three .txt output files were obtained from each participant. Each output file contains the following information:

a. Acceleration information in X (medio-lateral), Y (walking direction) and Z (vertical).

b. Angular velocity information from the gyroscopes in pitch, roll and yaw directions.

c. Magnetometers information in X,Y and Z directions. This provides information regarding earth's gravity field.

d. Orientation information calculated by the on-board processor in the accelerometer using information from all the accelerometers, gyroscopes and magnetometers. The algorithm is proprietary. This information is output either as a quaternion or as an embedded vector base (EVB). When quaternion information has been output it is converted to EVB information in the MatLab program reading the text file.An EVB is a description of an orthogonal 3D axes system. It describes a relation of the Local Coordinate System (LCS) to the Global Coordinate System (GCS). At initial quiet stance position, the initial orientation of each sensor was setparallel to GCS.

2.2.6.2 Data processing

All raw data were processed using Matlab 7.12.0 (R2011a) Student Version. This involved three stages before the final output with regards to accelerations and movements were obtained.

Stage 1: Identification of five environmental conditions (Colonnade, Dark, Busy, Cobbled and Quiet) from the raw acceleration data.

Raw data from lower trunk (L3) accelerometer output in the vertical direction was used to identify the five walking conditions. Previous work has shown that the vertical direction of trunk acceleration provides consistent acceleration patterns with peaks corresponding to heel strike in walking (Menz et al., 2003b, Kavanagh and Menz, 2008b). The five environmental conditions were identified manually. The initial peaks after a stop (I), and last peak before a stop (S), were used to define sections with the selection criteria that the peak had to be half the average amplitude of the majority of peaks. This time information was recorded as a point number with a point occurring at 100 recording per second. The time coordinates were then used as reference points for data selection in Stage 2. Figure 3 showed a graphical representation of raw accelerations data used for the selection of a walking environmental section.

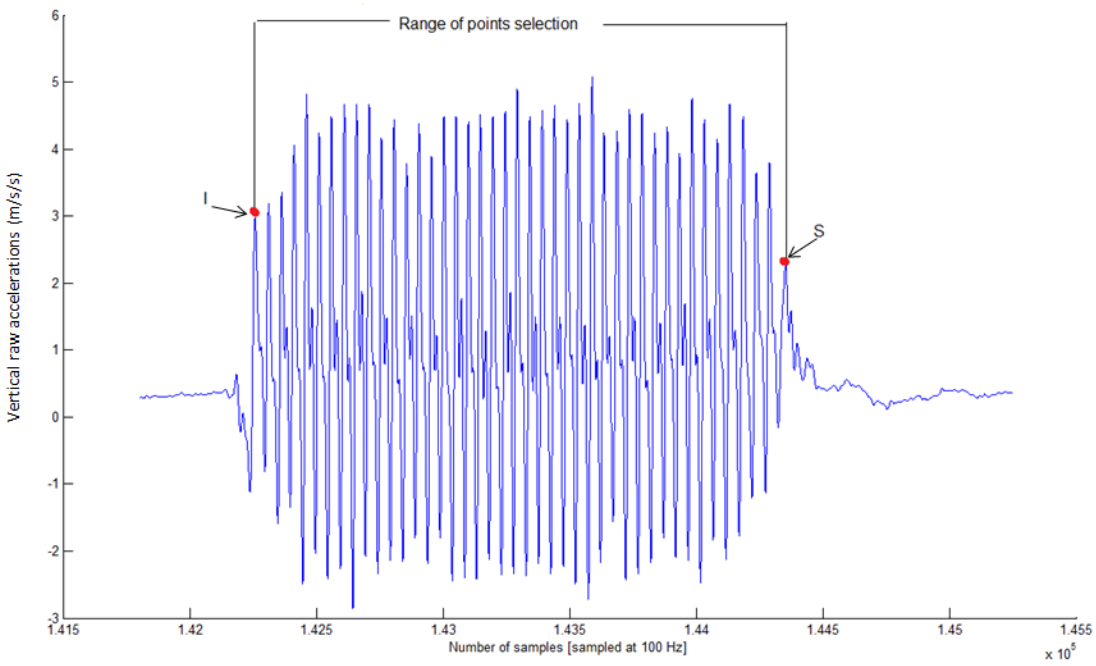


Figure 3 Graphical representation of raw accelerations data and the point selection to determine the environment section of interest.

The raw accelerations data was obtained at the trunk level of a healthy control participant while the person walked for a distance of 30 metres in a quiet section. Both 'I' and 'S' represent the first and the last point of selections respectively.

Stage 2: Extraction of gravity effects from raw accelerations using EVB information.

During the walking task, gravity (g) contributes to accelerations measured along all three axes of the local coordinate system. In order to subtract the gravity effect, first acceleration in the global coordinate system (AG) needs to be calculated. This can be achieved by rotating (transforming) the LCS so it is in agreement with the GCS. This is achieved by pre-multiplying the accelerations in the LCS (AL) by the transpose of the EVB (embedded vector base) of the LCS.

AG= EVB' x AL

Gravity's effect can now be subtracted from AG (Z axis) by subtracting - 9.81 m/s/s and this provides information about non-gravitational acceleration in GCS (IAG)

IAG= AG-g

Once the value of IAG has been established, the initial walking acceleration (IAW) can be obtained. Vertical acceleration is then correctly aligned. Aligning the 'Y' axis with the walking direction during each walking condition is achieved by averaging the direction of the Y axis for all time during the walking condition. The X axis is calculated as mutually perpendicular between Y and Z. The Z axis remains vertical as before.

Stage 3: Root mean square (RMS) for accelerations and orientation data in each environmental condition.

The RMS is a measure of dispersion of the data relative to zero and this value provides information on the average magnitude of accelerations or angular data (pitch, roll and yaw) in each direction during a walking trial. The RMS of accelerations and orientation data were displayed in all three directions (ML, AP and V). Figure 4 showed graphical representation of raw accelerations and orientation data of the head, neck and trunk.

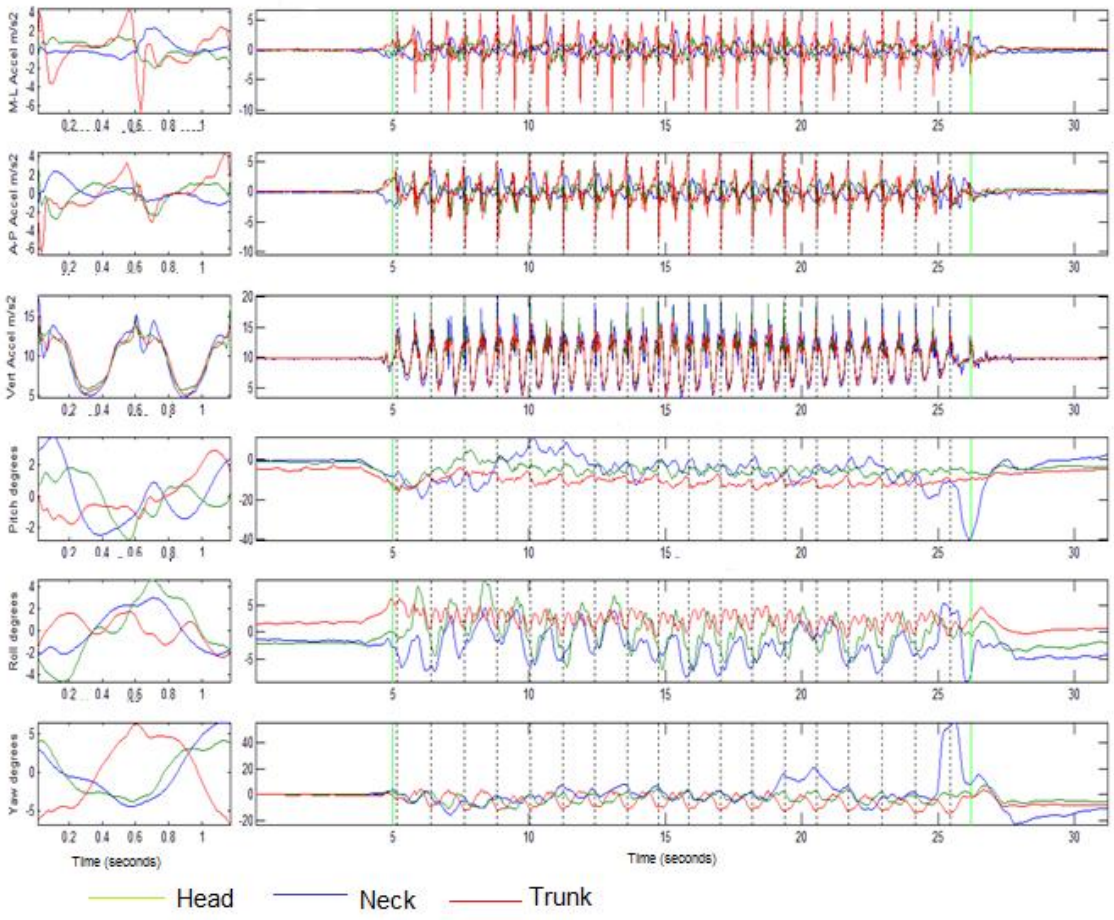


Figure 4 Example of raw accelerations and orientation data obtained from a person with a vestibular disorder during walking in a quiet section.

Stage 4: Normalization of the acceleration RMS data

There are clear evidences of a high correlation between upper body accelerations RMS and walking speed (Moe-Nilssen and Helbostad, 2004, Menz et al., 2003b). Higher acceleration RMS was noted when a person walked faster (Menz et al., 2003b). In the present study, normalised accelerations RMS (nRMS) was calculated by taking into account walking speed. In order to normalise accelerations RMS, correlation between this factor and walking speed for individual environmental segments was first determined and

regression coefficients values were obtained. Subsequently, raw acceleration RMS was speed normalised using the following equation:

Normalised acceleration RMS (nRMS) = b_0 + [b_1 x walking velocity]

Both b_0 and bi were regression coefficients wherein b_0 was the y-intercept value and b1 represented the gradient of the regression line. Normalisation was only performed for accelerations data.

2.2.7 Analysis

Statistical analyses were performed using SPSS version 17 (SPSS Inc., Chicago, Ill). Normal distribution of the gait and accelerometers outcome measures was assessed by Kolmogorov-Smirnov test. When data was normally distributed, an independent sample t-test was used to compare between-group differences. For non-normally distributed and ordinal data, a Mann-Whitney U test was performed. One-Way ANOVA was conducted to examine effect of environmental conditions on the postural strategies used by each group. Spearman's correlation was performed to investigate the relationship between total acceleration data and self-reported outcome measures (SVQ, ABC, VADL, VSS and HAD), objective outcome measures (TUG and FGA) and spatio-temporal variables (gait speed, walking duration and steps) within-groups. Only significant findings were reported in the result section (2.3). Significant results for all tests were assumed if $p<.05$.

2.3 RESULTS

Age significantly differ between-groups with Group PV participants significantly older than Group C [$z=-2.34$; $p<0.05$]. Four participants from Group PV showed normal findings on vestibular assessments and these participants were recruited based on medical examination and/or clinical history that was compatible with uncompensated vestibular disorder as a consequence of vestibular neuritis. Demographic and clinical characteristics of participants upon recruitment are displayed in Table 1.

Table 1 Demographic and clinical characteristics of participants upon recruitment

Variable	Group PV	Group C
Age (year) (mean, range)	47 (20-64)	37 (21-62)
Gender,n Male, n (%) Female, n (%)	 8 (38.1) 13 (61.9)	 14 (46.7) 16 (53.3)
Symptom duration (months)(mean, range)	43 (5-204)	NA
Diagnosis, n Vestibular neuritis	 13	NA
Labyrinthitis	2	
Meniere's Disease	1	
Migraine vertigo	2	
Idiopathic	3	
Vestibular findings, n		NA
CP (+DP)	13 (3)	
DP	1	
Normal caloric	4	

Abbreviations: Group C=healthy control group; Group PV= patients with a unilateral peripheral vestibular disorder; CP=canal paresis either based on Fitzgerald - Hallpike caloric testing as measured by the duration parameter using the Jongkees formula of more than 8% in the absence of optic fixation or ≥20 % asymmetry for video-nystagmography; DP = directional preponderance either ≥ 12% based on Fitzgerald - Hallpike caloric testing or ≥ 20 % asymmetry for video-nystagmography; CP (+DP)= testing showed both canal paresis and directional preponderance.

2.3.2 Self-reported measures

Significant differences were noted between-groups for all self-report measures. Compare to Group C, Group PV reported significantly lower (i.e. worse) on the ABC scale [z=-5.42; p<0.01] and showed a higher (i.e. worse) mean score for each VADL subscale [Functional: z=-6.13; p<0.01; Ambulation: z=-6.24; p<0.01; Instrumental: z=-6.14; p<0.01], and for global vestibular (VSS-V) [z=-6.00; p<0.01], somatic anxiety (VSS-A) [z=-5.07; p<0.01], non-somatic anxiety (HAD-A) [z=-4.54; p<0.01], depression (HAD-D) [z=-4.73; p<0.01] and visual vertigo (SVQ) scores [z=-5.04; p<0.01].

Significant correlations were noted between age and HAD-A [r=-0.51,p<0.05] as well as VSS-V scores [r=-0.48; p<0.05] in Group PV, whereby lower anxiety and global vestibular symptoms were associated with increase age. Descriptive data for all questionnaire scores is displayed in Table 2.

Seventy-one percent of Group PV (n=15) and 3% of Group C (n=1) scores were abnormal with scores outside the normative range for the SVQ. Hospital Anxiety and Depression subscales, HAD-A and HAD-D scores indicated borderline or higher scoresfor 57% (n=12) and 71% (n=15) of Group PV participants respectively. An increased falls risk was indicated for 38% of Group PV participants (n=8) based on ABC scores. For the VSS-V, 90.5% (n=19) of Group PV had scores outside the normative range. All Group C participants reported scores within normal range on ABC, HAD and VSS.

Table 2 Mean (SD) score for questionnaires data

	Group PV Mean (SD)	Group C Mean (SD)
VADL-F	2.59 (0.28) *	1.01 (0.01)
VADL-A	3.20 (0.33) *	1.01 (0.01)
VADL-I	3.39 (0.38) *	1.01 (0.01)
VSS-V	1.07 (0.15) *	0.05 (0.01)
VSS-A	1.24 (0.17) *	0.25 (0.05)
HAD-A	9.43 (0.94)*	3.73 (0.42)
HAD-D	7.19 (0.90) *	1.43 (0.36)
SVQ	1.54 (0.21) *	0.24 (0.10)
ABC	65.70 (4.40) *	96.00 (0.85)

Abbreviations: Group PV= patients with a unilateral peripheral disorder; Group C= control healthy; SVQ=Situational Vertigo Questionnaire;HAD-A=Hospital Anxiety and Depression (Anxiety scale);HAD-D=Hospital Anxiety and Depression (Depression scale); VSS-V=Vertigo Symptom Scale (common vestibular symptoms); VSS-A=Vertigo Symptom Scale (autonomic and somatic anxiety symptoms);ABC=The Activities Specific Balance Confidence Scale; VADL-F= Vestibular Activities of Daily Living Scale (functional subscale); VADL-A= Vestibular Activities of Daily Living Scale (ambulation subscale); VADL-I=

Vestibular Activities of Daily Living Scale (Instrument subscale). The asterisk (*) indicates a significant between-group difference ($p<0.01$).

2.3.3 Functional measures

A significant between-group difference was noted for FGA scores with Group PV significantly lower (i.e. worse) scores than Group C [$z=-6.1$; $p<0.01$]. Group PV took significantly longer time to complete TUG [$t(22)=2.26$; $p<0.05$]. Age significantly correlated with TUG [$r=0.47$; $p<0.05$] and FGA [$r= -0.47$; $p<0.01$] for Group PV whereby increasing age was associated with higher (i.e. worse) TUG and lower (i.e. worse) FGA scores. It was noted that mean age of Group PV was significantly higher than Group C thus age could be one of contributing factor to FGA and TUG scores in Group PV. Descriptive data for functional and gait outcome measure is shown in Table 3.

2.3.4 Urban walking analysis

2.3.4.1 Gait speed and duration

Significant between-group differences were noted for walking velocity across all environmental conditions except for the “busy” section [Colonade: $t(49)=-3.94$; $p<0.01$; Dark: $t(49)=-2.50$; $p<0.05$; Busy: $t(29)=-1.82$; $p>0.05$; Cobbled: $t(49)=-2.90$; $p<0.05$; Quiet: $t(49)=-2.57$; $p<0.05$]. The time required to complete the urban walking task also significantly longer for Group PV [$z=-3.28$, $p=0.01$]. Descriptive data for walking speed, duration and number of steps taken for each group is displayed in Table 3.

Table 3 Mean (SD) for the functional assessment and gait outcome measures

	Group PV	Group C
FGA	23.62 (4.65) **	29.63 (0.56)
TUG	9.01 sec (3.05) *	7.46 sec (0.88)
Urban gait		
Number of steps taken to complete route	1155.53 (168.19)	1121.13 (133.3)
Walk duration, minutes	17.53 (2.86) **	15.28 (1.24)
Urban walking velocity (ms^{-1})		
Colonade	1.28 (0.21) **	1.47 (0.14)
Dark	1.33 (0.25) *	1.48 (0.15)
Busy	1.23 (0.26)	1.35 (0.15)
Cobbled	1.33 (0.27) *	1.52 (0.18)
Quiet	1.35 (0.25) *	1.50 (0.17)

Abbreviations: Group PV= patients with a unilateral peripheral disorder; Group C= control healthy; FGA=functional gait assessment; TUG=Time up and go. The asterisk (*) denotes a significant between-group difference (*$p<0.05$; **$p<0.01$)

2.3.4.2 Acceleration patterns

2.3.4.2.1 Overall normalised accelerations patterns

Significant between-group differences were noted for total normalised accelerations RMS in both the AP [z= -2.05; p=0.04] and V [z=-2.91; p=0.00] directions with Group PV demonstrating significantly reduced accelerations compared to Group C. Mean total nRMS (SD) for Group PV and Group C in the AP direction were 1.15ms^{-2} (0.17) and 1.26ms^{-2} (0.15) respectively as well as 2.5ms^{-2} (0.54) and 2.96ms^{-2} (0.46) in V directions respectively.

Normalised acceleration RMS (nRMS) patterns for the head, neck and trunk across the five environmental conditions for both groups are illustrated in Fig. 5. Group PV had significantly smaller mean nRMS accelerations at the head and neck compared to Group C for each individual environmental condition in the vertical direction only [VHead: Col z= - 4.33 p=0.00; Dark t(49)= - 2.97 p=0.01; Busy t(49)= - 2.76 p=0.01; Cobbled t(49)= - 3.7 p=0.00; Quiet t(49)= -2.9 p=0.01 and VNeck: Col z=-4.01 p=0.00; Dark t(49)= - 2.41 p=0.02; Busy t(49)= -2.5 p=0.02; Cobbled t(49)= - 3.28 p=0.00; Quiet t(49)= - 2.42 p=0.02].

Mean trunk nRMS accelerations in the ML direction were significantly smaller in Group PV except for quiet condition [Colonade z=-3.42 p=0.00; Dark t(49)= -2.48 p=0.02; Busy t(49)= - 3.03 p=0.00; Cobbled t(49)= -2.7 p=0.01; Quiet z= -1.89 p=0.06 (n.s)]. A significant reduction of trunk accelerations were also noted in both the AP and V directions across the environmental conditions in Group PV [AP:Colonade z= - 3.92 p=0.00; Dark t(49)= -3.39 p=0.00; Busy t(49)= - 3.58 p=0.00; Cobbled t(49)= - 3.67 p=0.00; Quiet z= - 2.81 p=0.00 and V: Colonade z= - 3.69 p=0.00; Dark t(49)= -2.32 p=0.02; Busy t(49)= - 2.41 p=0.02; Cobbled t(49)= - 3.12 p=0.00; Quiet t(49)= -2.42 p=0.02]. Between-group mean

differences of RMS accelerations at the head, neck and trunk levels are displayed in Table 4.

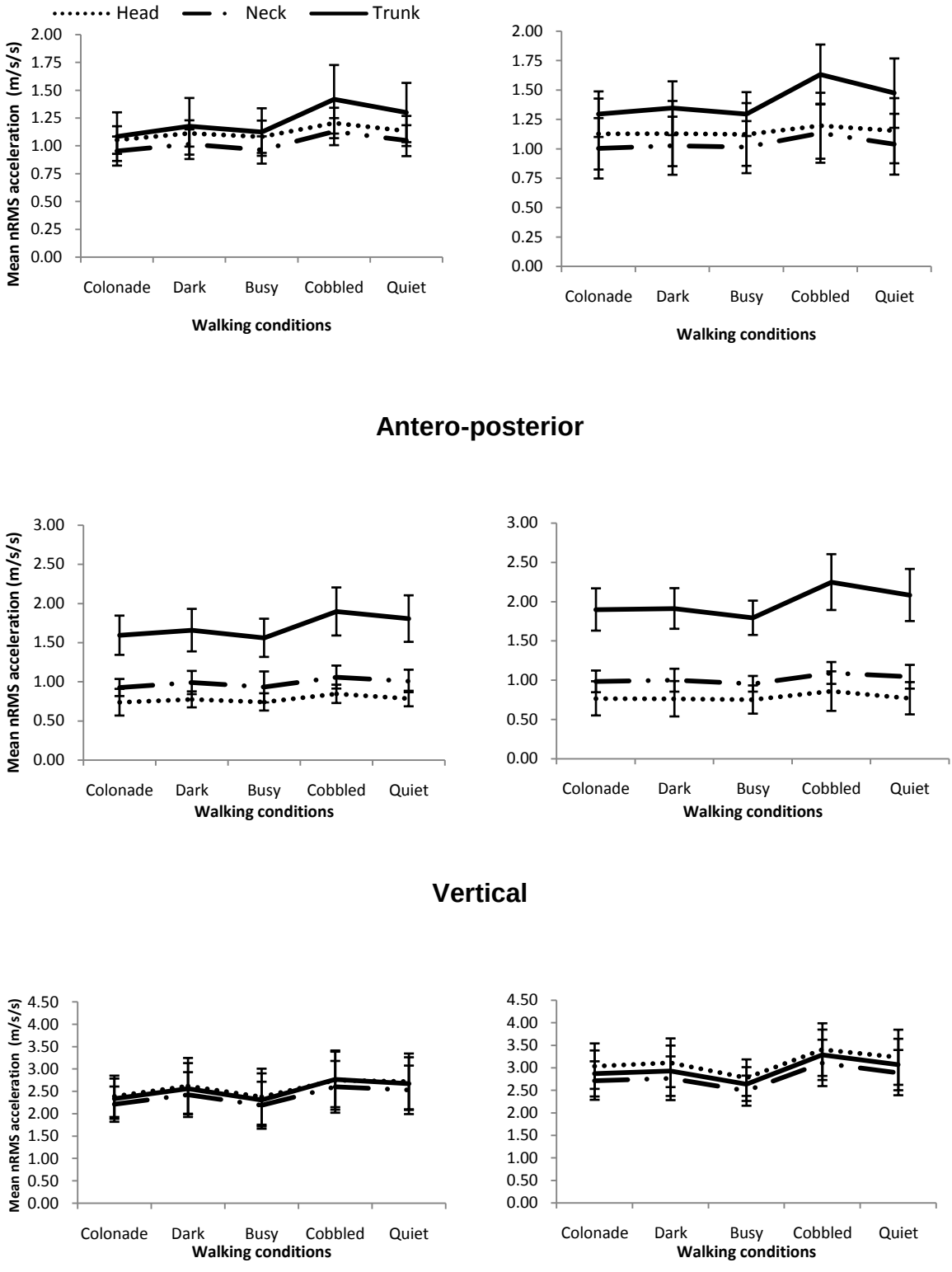


Figure 5 Acceleration patterns at the head, neck and trunk levels across the five environmental conditions. Abbreviation: nRMS=normalised accelerations RMS.

Table 4 Mean difference between groups, △(SD) of head, neck and trunk normalised RMS accelerations, nRMS (ms^{-2}).

		△ nRMS accelerations				
	Level	Environmental condition				
		Colonade	Dark	Busy	Cobbled	Quiet
ML	Head	-0.07 (0.06)	-0.02 (0.06)	-0.04 (0.06)	0.01 (0.06)	-0.02 (0.06)
	Neck	-0.05 (0.05)	-0.01 (0.05)	-0.05 (0.05)	0.00 (0.05)	0.01 (0.06)
	Back	-0.21** (0.06)	-0.17* (0.07)	-0.17** (0.06)	-0.21* (0.08)	-0.17 (0.08)
AP	Head	-0.03 (0.06)	0.01 (0.05)	-0.01 (0.04)	-0.02 (0.05)	0.01 (0.04)
	Neck	-0.06 (0.04)	-0.01 (0.04)	-0.02 (0.05)	-0.03 (0.04)	-0.03 (0.04)
	Back	-0.31** (0.07)	-0.25** (0.08)	-0.23** (0.07)	-0.35** (0.10)	-0.28** (0.09)
V	Head	-0.65* (0.14)	-0.49* (0.16)	-0.40* (0.14)	-0.65* (0.18)	-0.51* (0.18)
	Neck	-0.50* (0.12)	-0.34* (0.14)	-0.30* (0.13)	-0.51* (0.15)	-0.36* (0.15)
	Back	-0.54** (0.14)	-0.37* (0.16)	-0.33* (0.14)	-0.52** (0.17)	-0.40* (0.16)

The negative values indicate the nRMS was smaller in patients group as compared to healthy control group. Abbreviations: nRMS= the difference of mean normalised RMS accelerations between groups; ML = medio-lateral; AP = antero-posterior; V=vertical. The asterisk (*) denotes significant between-group difference (* $p < 0.05$; ** $p < 0.01$).

2.3.4.2 Effect of environmental conditions on within-group RMS accelerations.

A significant effect of environment conditions on mean head nRMS accelerations was noted for Group PV in both ML [F(4,100)=4.09; p=0.00] and AP directions [F(4,100)=2.59; p=0.04]. For the ML direction, head nRMS acceleration was significantly lesser in both colonnade and busy condition compared to the cobbled environment. In the AP direction, however, the significant effect observed earlier was no longer evident after post-hoc analysis. For Group C, a significant effect of environmental conditions on head nRMS acceleration was noted in the vertical direction only [F(4,145)=5.66; p=0.00] with post-hoc Bonferroni test revealed significant lesser accelerations in the busy compared to the cobbled and quiet environments.

A significant effect of walking condition on mean neck nRMS acceleration was noted for all directions [ML: F(4,100)=6.26 p=0.00; AP:F(4,100)=2.80; p=0.03; V: F(4,100)=2.76; p=0.03] for Group PV and in the AP and V directions for Group C [AP: F(4,145)=4.71; p=0.00; V:F(4,145)=7.4; p=0.00]. On post-hoc Bonferroni analysis, the significant effect observed in the vertical direction for Group PV was no longer evident.

In both groups, the environmental condition significantly affected nRMStrunk accelerations in all directions [Group PV: ML: F(4,100)=6.13; p=0.00; AP:F(4,100)=5.73; p=0.00; V: F(4,100)=2.66; p=0.04 and Group C: ML:

F(4,145)=11.4; p=0.00; AP: F(4,145)=11.35; p=0.00; V:F(4,145)=6.42; p=0.00]. However, the significant effect observed in vertical direction for Group PV was no longer evident following post-hoc Bonferroni analysis. Figure 6,7 and 8 illustrates the effect of environmental conditions on head, neck and trunk accelerations.

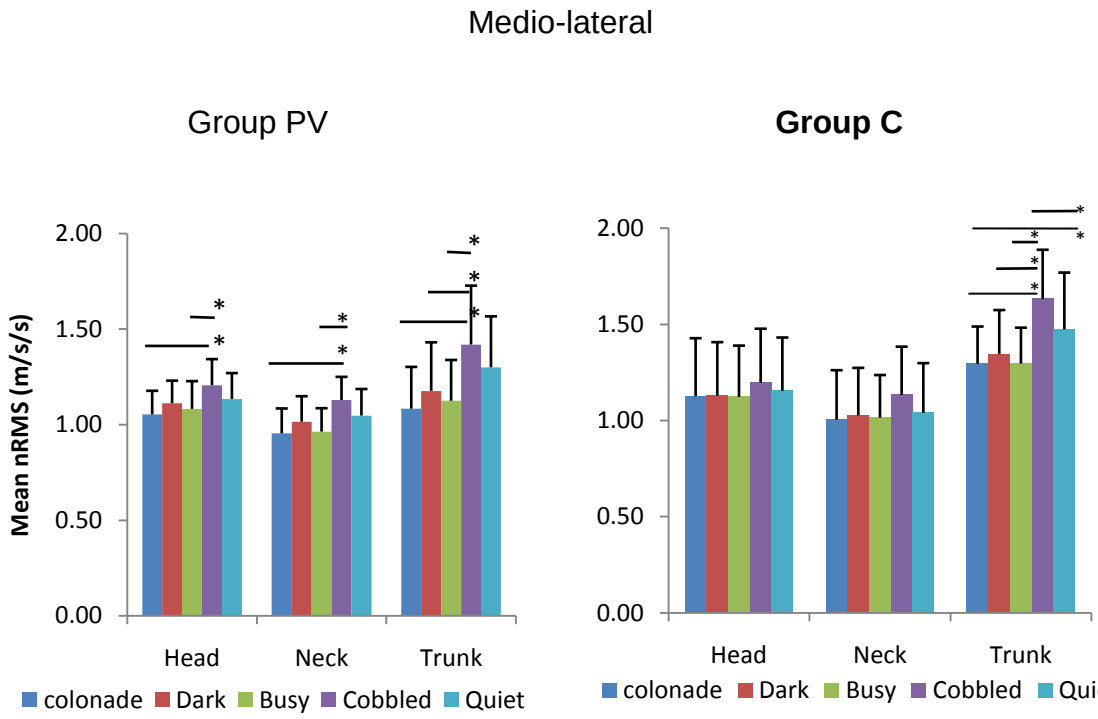


Figure 6 Effect of environmental conditions on ML nRMS acceleration at head, neck and trunk.

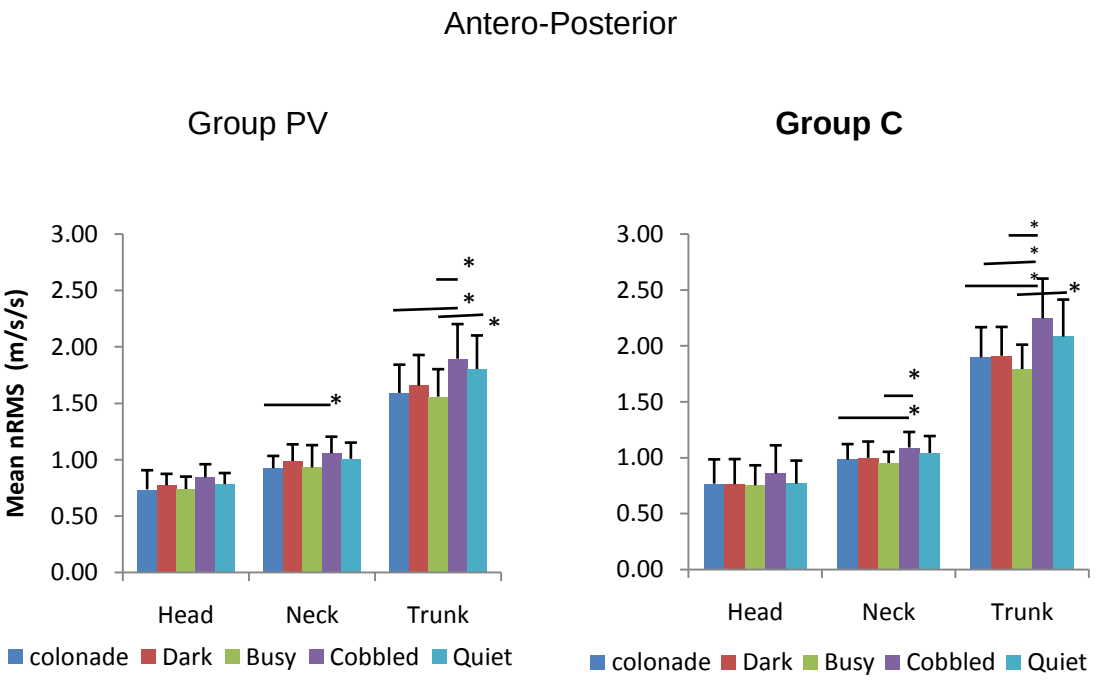


Figure 7 Effect of environmental conditions on AP nRMS acceleration at head, neck and trunk.

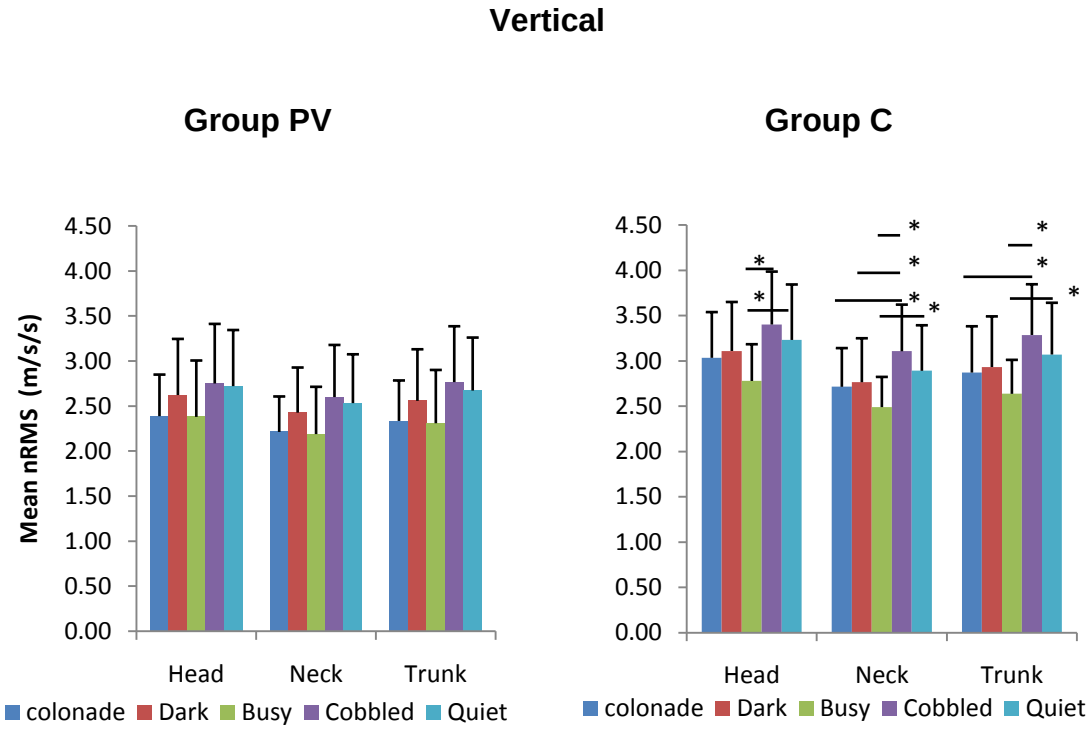


Figure 8 Effect of environmental conditions on V nRMS acceleration at head, neck and trunk.

Abbreviation: nRMS=normalised accelerations RMS. The asterisk (*) indicates significant between- environmental condition difference.

2.3.5 Angular movement patterns

2.3.5.1 Overall angular movement patterns

A significant between-group difference was noted only at the neck level for mean pitch RMS in the busy condition [z=-1.93; p=0.05]. Between-group mean differences of angular movement at head, neck and trunk are displayed in Table 5.

Table 5 Mean difference (SED) of angular movement RMS at the head, neck and trunk levels in pitch, roll and yaw directions between groups.

Angular movement RMS (degrees)	Level	Environmental condition				
		Colonade	**Dark**	**Busy**	**Cobbled**	**Quiet**
Pitch	Head	0.04 (0.99)	-0.26 (0.99)	-0.31 (0.74)	-0.27 (0.80)	-0.03 (0.74)
	Neck	-0.19 (0.14)	-0.24 (0.20)	-0.33* (0.22)	-0.04 (0.20)	-0.03 (0.17)
	Trunk	-0.28 (0.21)	-0.34 (0.20)	-0.35 (0.19)	-0.18 (0.21)	-0.21 (0.18)
Roll	Head	-0.10 (0.31)	-0.12 (0.29)	-0.20 (0.24)	-0.30 (0.30)	0.15 (0.24)
	Neck	-0.07 (0.15)	-0.01 (0.17)	-0.06 (0.14)	0.06 (0.17)	0.16 (0.16)
	Back	-0.28 (0.17)	-0.28 (0.19)	-0.23 (0.17)	-0.07 (0.20)	-0.13 (0.21)
Yaw	Head	-1.34 (1.99)	-0.76 (1.52)	-1.39 (1.12)	0.08 (1.09)	1.65 (1.20)
	Neck	1.04 (0.72)	-0.12 (0.51)	-1.28 (0.81)	0.87 (0.57)	0.07 (0.69)
	Back	0.56 (0.64)	-0.10 (0.58)	-0.69 (0.77)	0.25 (0.65)	0.24 (0.72)

The negative values indicate smaller values in patients compared to healthy control group. The asterisk (*) indicates significant between-group difference ($p<0.05$).

2.3.5.2 Effect of environmental conditions on within-group mean angular movements

A significant correlation was noted only between age and mean yaw RMS in the busy condition for Group PV [r=-0.52; p<0.05]. For Group PV, one-way ANOVA showed a significant effect of environmental conditions on mean yaw RMS at both the neck [F(4,100)=3.24; p=0.02] and trunk [F(4,100)=2.79; p=0.03] levels. Post-hoc analysis revealed mean yaw RMS at the neck level was significantly higher for the “busy” compared to both the colonnade [mean difference (MD)=2.21; SED= 0.74; p<0.05] and quiet [MD=2.20; SED=0.74; p<0.05] environments. Yaw RMS at the level of the trunk was significantly greater for the “busy” compared to the colonnade [MD=2.35; SED= 0.79; P<0.05] environment.

For Group C, significant effect of environmental conditions at the head level was noted only in yaw RMS [f(4,145)=2.74; p=0.03]. However after the post-hoc analysis, the significant effect observed earlier in yaw RMS was no longer evident. At neck level, significant differences were noted for mean pitch RMS [f(4,145)=18.89; p=0.00] and yaw RMS [f(4,145)=2.7; p=0.03]. In pitch, significant differences occurring between the busy and colonnade environments as indicated by the post-hoc [MD= 0.44; SE=0.15; p<0.05]. While in yaw, significant differences were noted between the dark and colonnade [MD= 2.11; SE=0.15; p<0.01] as well as between the busy environment compared to the other four environmental conditions [Colonade: MD= 4.53; SE=0.55; p<0.01; Dark: MD= 2.42; SE=0.55; p<0.01; Cobbled: MD= 2.99; SE=0.55; p<0.01; Quiet: MD=3.56; SE=0.55; p<0.01] by which the former in each comparison was

always greater. One way ANOVA showed significant environmental conditions effect on the mean trunk yaw RMS [f(4,145)= 12.16; p=0.00] whereby higher trunk yaw movement noted in the busy environment compared to the colonnade [MD=3.60; SE=0.54; p<0.01], dark [MD=2.25; SE=0.54; p<0.01] and quiet [MD=2.49; SE=0.54; p<0.01] environments as indicated by the post-hoc. Similar pattern was also observed between the cobbled and the colonnade environments with the former showed greater yaw angular movement [MD=2.08; SE=0.54; p<0.01].

For both groups, different environmental conditions were not significantly change head angular movements in pitch, roll and yaw. Figs. 9, 10 and11 illustrate the within-group effect of environmental conditions.

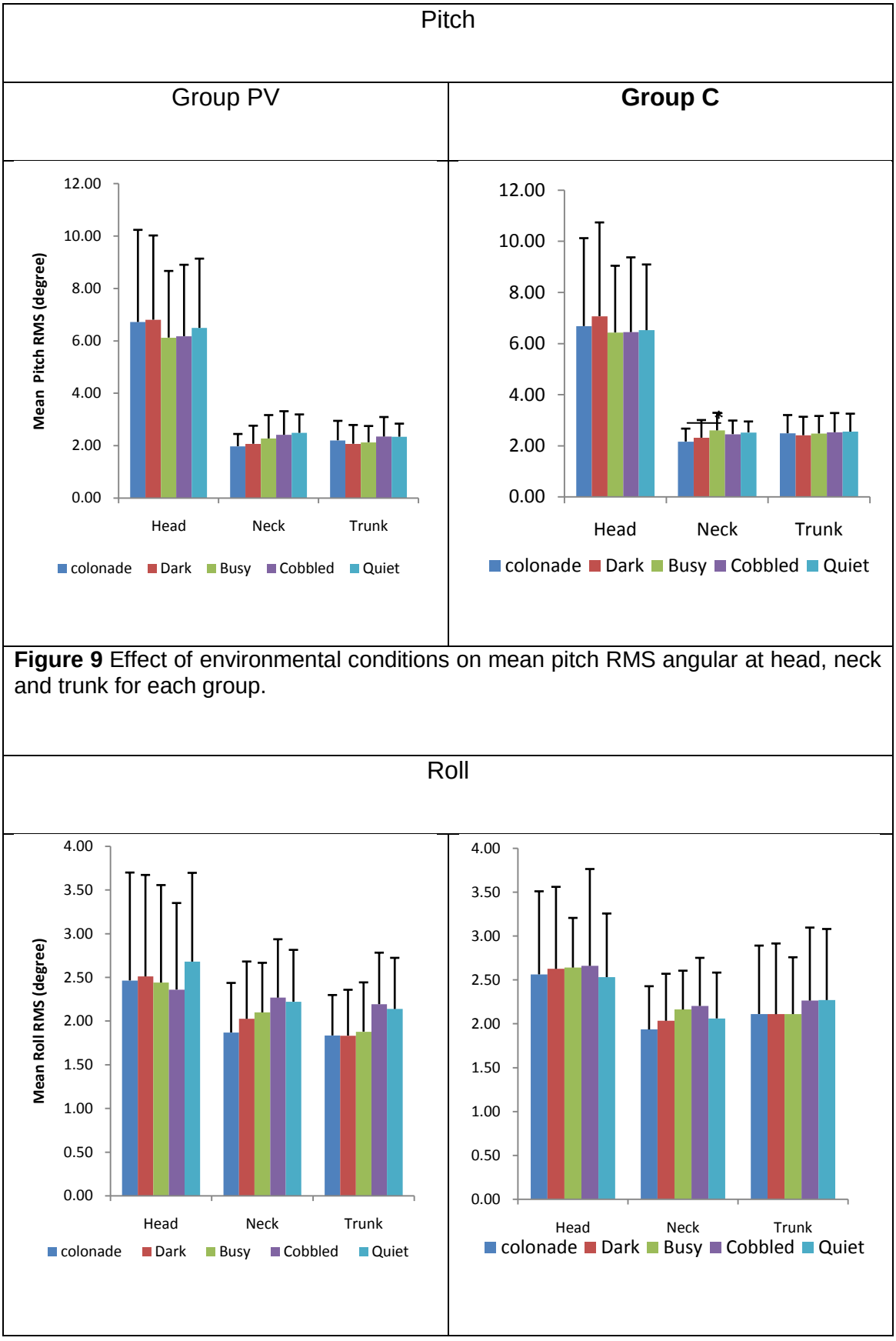


Figure 9 Effect of environmental conditions on mean pitch RMS angular at head, neck and trunk for each group.

Figure 10 effect of environmental conditions on mean roll RMS at head, neck and trunk for each group.

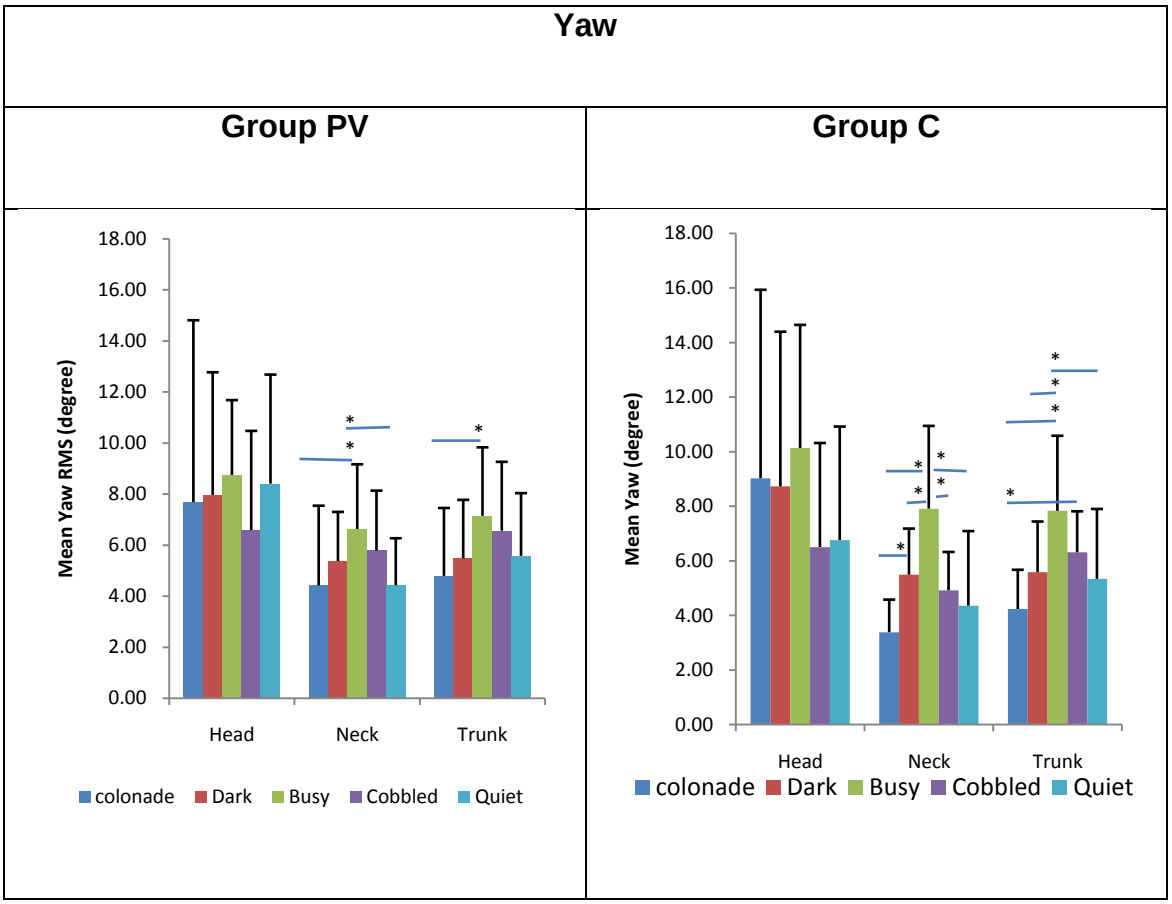


Figure 11 Effect of environmental conditions on mean yaw RMS at head, neck and trunk level for each group.

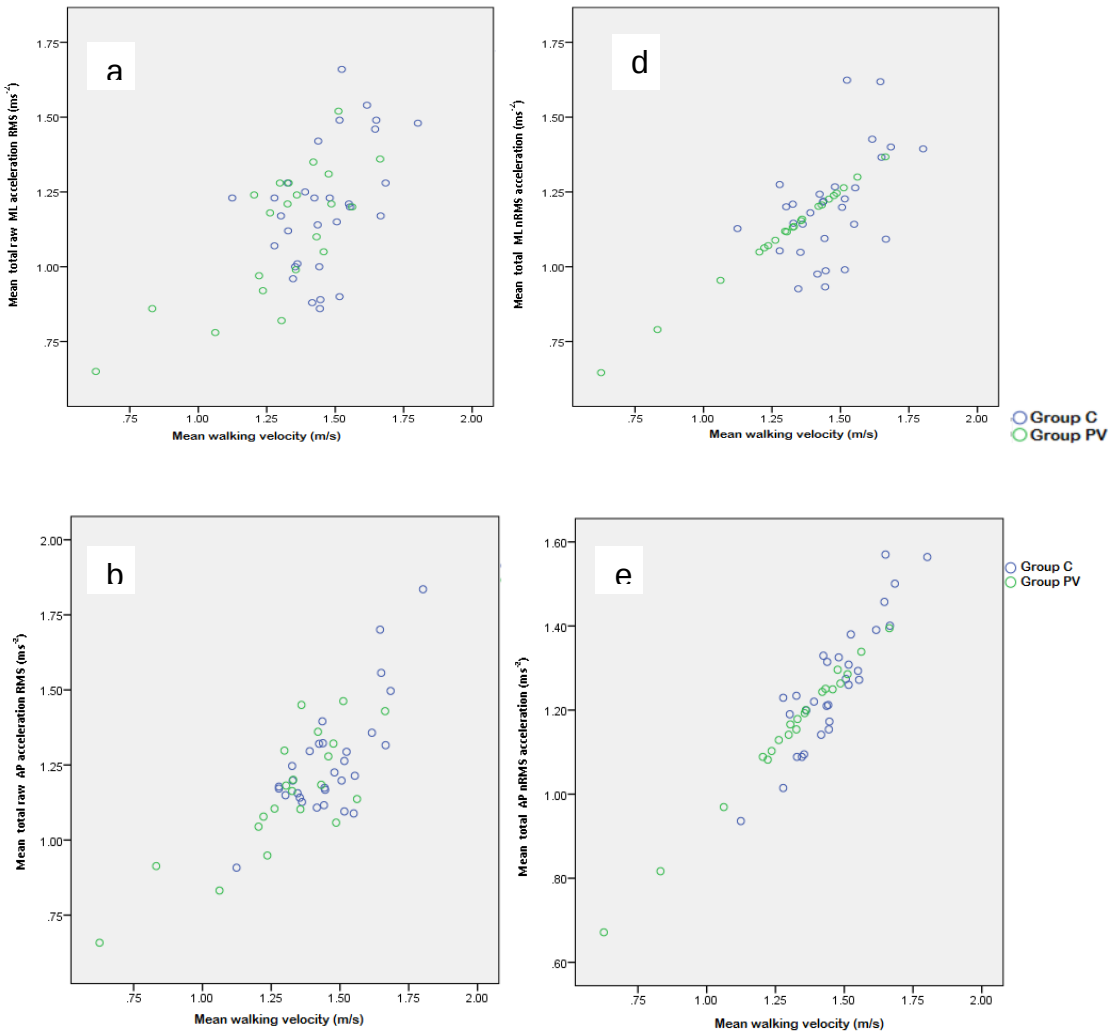
The asterisk (*) indicates significant differences between specified conditions.

2.3.6 Relationship between mean total nRMS accelerationsand gait spatio-temporal parameters.

Figure 12 shows the relationship between preferred walking speed and the mean total raw accelerations and nRMS accelerations in both groups. In Group C, weak to strong positive correlations were noted between the mean total raw acceleration RMS for all directions and mean walking speed (ML: r=0.39; p=0.31; AP: r=0.54; p=0.02 and V: r= 0.72; p=0.00). Although normalised accelerations (nRMS) were still significantly associated with walking speed,

nRMS in the ML direction was weakly influenced by walking speed (ML: r=0.57; p=0.02). On the other hand, for Group PV, normalised accelerations RMS (nRMS) was strongly associated with walking speed [ML: r=0.99; p=0.00; AP: r=0.99; p=0.00 and V : r=1].

Age did not significantly correlate either with mean raw total accelerations RMS or mean total nRMS accelerations in any direction for both groups (p<0.05).



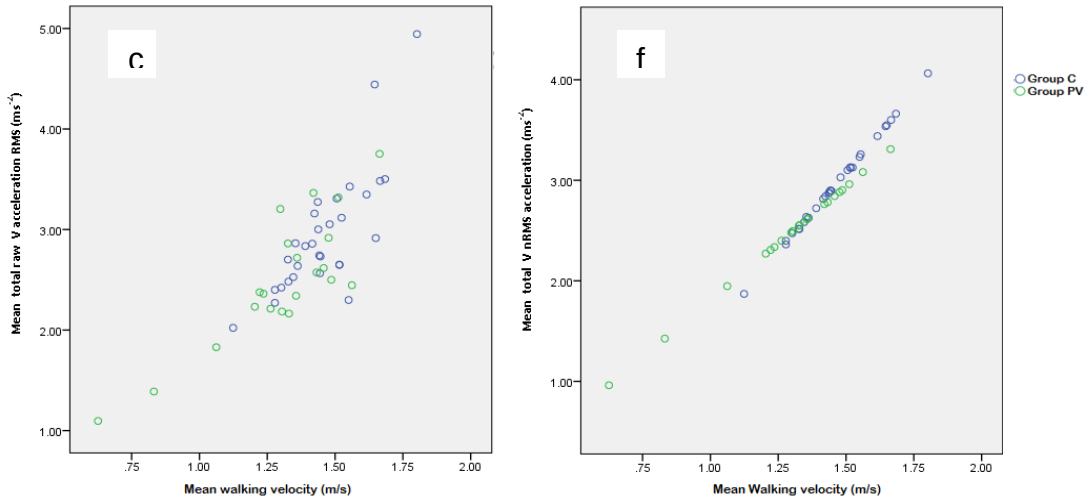


Figure 12 Scatterplot showing the relationship between gait speed and RMS accelerations.

The effect of gait speed on the mean total raw accelerations RMSin ML (a), AP (b) and V (c) directions and the mean total normalised accelerations (nRMS) in ML (d), AP (e) and V (f) directions.

For both groups, walking duration was inversely correlated with nRMS acceleration in all directions whereby shorter walking duration correlated with higher accelerations [For Group PV ML: r=-0.84; p=0.00; AP: r= -0.81; p=0.00; V: r=-0.84; p=0.00 and Group C ML: r=-0.37; p=0.04; AP: r= -0.69; p=0.00; V: r=-0.76; p=0.00]. A significant negative correlation was noted between walking steps and vertical nRMSacceleration in Group C [V: r= -0.41; 0.03].

2.3.7 Relationship between mean total nRMS accelerations and objective and subjective outcome measures in patients group.

For subjective outcome measures, a significant positive correlation was noted between the mean ABC score and nRMS accelerations in each direction [ML:

r=0.5; p=0.02; AP: r= 0.53; p=0.01; V: r=0.51; p=0.02) whereby higher nRMS accelerations were noted with increased balance confidence levels.

For objective outcome measures, both FGA and TUG were significantly correlated with the mean total nRMS accelerations. Increased total nRMS accelerations in each direction significantly correlated with increased (i.e. better) FGA scores [ML: r=0.69; p=0.00; AP: r= 0.70; p=0.00; V: r=0.69; p=0.00]. While lower (i.e. better) TUG scores associated with increased total nRMS accelerations [ML: r=-0.67; p=0.00; AP: r= -0.66; p=0.00; V: r=-0.67; p=0.00].

2.4 DISCUSSION

This study investigated postural stability, using data from accelerometers, during walking in urban environments between healthy-control adults and patients with a vestibular disorder. Association between the accelerometry data during urban walking and subjective clinical scales, functional capacity and spatio-temporal gait parameters were also investigated.

The following discussion is separated into the following sections: (a) Gait patterns b) Postural stability during walking in different urban environments(c) Relationship between urban walking and standard clinical scales and assessments (d) Clinical implications.

A) Gait pattern changes

Our results showed that Group PV walked significantly slower and took longer duration of walking compared to healthy-control group (Group C) in almost all walking sections. No significant between-group difference was noted for walking

speed in a “busy” environment and this could possibly due to the fact that participants need to adjust their walking speed to accommodate walking through a ‘crowd’ such as to avoid bumping into people or vice versa. Reduced walking speed was previously reported in individuals with vestibular disorders compared to control group (Borel et al., 2004, Mamoto et al., 2002). It is suggested that adjustment to spatio-temporal gait parameters in individuals with a peripheral vestibular disorder is to compensate for dynamic instability during walking (Borel et al., 2004; Mamoto et al. 2002, Marchetti et al., 2008). Previous study have shown steps taken over a specific walking distance was not significantly different between healthy and patients with a unilateral vestibular disorder (Cohen and Sangi-Haghpeykar, 2011). This finding was in line with the current study.

B) Postural stability during walking in different urban environments

Relative to Group C, reduced trunk accelerations in the ML, AP and V directions were noted in almost all environmental conditions for Group PV. Reduced head and neck vertical accelerations were also noted for Group PV. Comparisons of the head, the neck and the trunk accelerations data during walking in real urban environments between healthy controls and individuals with a confirmed peripheral vestibular disorder have not been reported previously.

Patients with vestibular dysfunction, for which the central nervous system has not compensated, commonly report unstable gaze during active head movements. This is associated with impaired VOR which is a primary mechanism for gaze stability during head movement, especially at high velocity. Degradation of visual acuity is noticeable objectively in patients with unilateral

vestibular disorder although many patients may not complaint (Roberts and Gans, 2007, Dannenbaum et al., 2009, Badaracco et al., 2010). To enable optimum function of the impaired VOR in this patient, head movement need to be controlled. Head-trunk coordination helps organize inputs from the visual, somatosensory and vestibular systems to optimize dynamic postural control and gaze stabilization functions while walking. Therefore, it is hypothesized that reduced trunk acceleration during walking was implemented as a strategy to control head stability in Group PV.

Reduced vertical head velocities during a walking task on a motorized treadmill at a controlled walk speed in patients with unilateral vestibular dysfunction (uVD) compared to healthy has previously been reported (Crane and Demer, 2000). The authors suggested that limiting the head movement probably enabled compensation for impaired VOR gain in uVD patients. Current study finding was in line with previous work that found individuals with a peripheral vestibular disorder have reduced head accelerations in vertical direction. It is hypothesised that reduce head accelerations lessens vestibular stimulation thereby avoiding exacerbation of dizziness symptoms and unsteadiness due to an uncompensated vestibular disorder.

Acceleration patterns during walking have been investigated in different groups including healthy young (Menz et al., 2003b) and older adults (Menz et al., 2003c), frail community-dwelling older adults (Menz et al., 2003a), older adults in pathologic group (Parkinson Disease) and fallers (Latt et al., 2009). Older adults and patients with Parkinson Disease (PD) who experience falls demonstrate reduced head and trunk RMS accelerations compared to healthy younger adults and patients with PD respectively (Menz et al., 2003c, Latt et al.,

2009). Community-dwelling older adults who were at higher risks for falls showed smaller amplitude and less rhythmic patterns of head and pelvis accelerations as compared to low-risk fallers older adults (Menz et al., 2003a). In addition, changes in gait characteristics (i.e. walking speed) were also noted in these groups as in our patients with unilateral peripheral vestibular dysfunction.

Taken together the similar changes in acceleration patterns and gait characteristics found in previous and current studies, suggest that adjustment in gait patterns are necessary for a greater control over trunk motion, which helps head stabilization.

No study to date has investigated the effect of different urban walking environments on acceleration patterns of the head, neck and trunk during walking. Effects of different walking surfaces i.e. level ground or uneven surface on acceleration patterns in young adults has previously been reported (Menz et al., 2003b). A study reported that, in young healthy adults, walking on an unpredictable uneven walkway (i.e. layers of artificial grass, foam and wooden blocks walkway) compared with a flat walkway resulted in higher acceleration at the pelvis, however the head accelerations remained relatively stable (Menz et al., 2003b). Although the aforementioned study was conducted in a controlled laboratory setting, similar findings were noted for Group C individuals in the current study, particularly for head and trunk nRMS accelerations in the ML and AP directions. Unlike the healthy control group, Group PV showed higher head and neck nRMS in the ML direction, in addition to increased trunk accelerations. This suggests that head stability in the ML direction has been compromised in Group PV while they walk on a cobbled street. Overall, Group PV had reduced

trunk movements compared to the healthy control group. It is known that the trunk plays an important role in attenuating gate-related oscillations from impacting head motion during walking (Cappozzo, 1984). Efficient coordination of trunk and lower limbs movements provides stability for upright posture during walking. Our findings showed that patients with a vestibular disorder have difficulty controlling trunk movement and maintaining head stability particularly when walking on irregular terrain. It has been reported previously that modulation of ML accelerations is not only linked to shock absorption but also to walking balance. Greatest attenuation of upper body accelerations in upward direction (i.e. from lower trunk to head) noted in the ML direction has been suggested to provide stability to head-on-trunk as a platform for optimal vestibular and visual information processing (Wilhelmsen et al., 2010). It is likely that this function is impaired in patients with vestibular disorder. Therefore normalised RMS accelerations in the ML direction may potentially be useful as a measurement for gait abnormality (Wilhelmsen et al., 2010, Sekine et al., 2013).

It was noted that, in Group C, walking on a cobbled street compared to the other walking environments led to higher head and neck accelerations in the vertical direction, in addition to increased trunk acceleration. This could possibly relate to the vertical ground reaction force (GRF). Association of GRF, vertical impact and walking speed has been studied extensively whereby GRF increased linearly with gait speed within a specified speed during walking (Keller et al., 1996). As this force transmitted through the body, neuromuscular systems and joints contribute to attenuating the force impact from reaching the head. The trunk acts as the attenuator, filtering excessive vibrations from reaching more superior levels thus reducing the impact and helping to maintain

a stable trajectory at head level (Prince et al., 1994). However the filtering effect has been shown to be minimal in the vertical plane (Prince et al., 1994). Although the GRF was not measured in the current study, walking velocity was significantly higher in Group C compared to Group PV in almost all environmental conditions. A higher walking speed produces a greater force upon foot contact with the ground during the gait cycle. Therefore the remaining vibrations passed to the head from the trunk are possibly enough to threaten upper body stability in vertical direction during walking which agrees with our findings showing increased vertical head accelerations.

In the current study, the head, the neck and the trunk rotations in pitch, roll and yaw directions were also investigated. Overall, mean RMS rotation of the head, neck and trunk in all three directions was not significantly different between Group PV and Group C for all walking environments. Previous studies have already demonstrated that during gait, head motion is minimised through the coordination of trunk and lower limbs movements (Pozzo et al., 1990). The lower limbs i.e. legs moved in a wider range relative to head and acts like actuators of head-trunk unit (Pozzo et al., 1990). This is believed to serve as a stable platform for visual and vestibular processing which is important which is important for maintaining postural stability control during walking (Pozzo et al., 1990, Lang et al., 2013). Our finding support previous reports regarding the importance of head movement control within the body postural control system during walking. Furthermore, the current study found that walking through a ‘busy’ section compared to other walking sections, produced higher mean rotation in the yaw direction at both the trunk and neck level, both groups. It was hypothesised that walking in a busy environment induce greater yaw rotation of

the trunk and neck as a way to accommodate walking through a 'crowded' to avoid bumping into people as well as a mechanism to keep the head stable.

These results indicate that walking in an urban environment provides challenges to postural stability control in patients with a unilateral vestibular disorder. Walking at a slower speed and reduced trunk accelerations could be compensatory mechanisms to provide stability in an upright position during walking in the patient group.

Association of urban walking postural control strategies with standard functional assessment and ABC scale.

Increased total nRMS acceleration, was significantly associated with an increased balance confidence level (ABC), higher (i.e. better performance) functional gait assessment (FGA) and reduced (i.e. better performance) time up and go (TUG) scores in Group PV. The ABC finding was in line with previous studies which showed significant association between the balance confidence, gait performance (Marchetti et al., 2011) and self-perceived handicap (Whitney et al. 1999, Whitney et al., 2004b). Although the ABC scale has been shown to discriminate recent fallers from non-fallers in an older adults population, but the scale has not been shown to correlate with falls in patients with unilateral vestibular disorders (Marchetti et al., 2011). An ABC score of less than 80% has been considered abnormal (Herdman et al., 2012, Myers et al., 1998). However further research is warranted to identify to what extend of abnormal balance confidence may cause gait abnormality in patients with unilateral vestibular disorders.

A significant association was also noted between nRMS acceleration and both FGA and TUG in Group PV only whereby higher total normalised RMS acceleration was associated with higher FGA score (i.e. better performance) and shorter time for TUG. Both FGA and TUG have been used to assess functional mobility in different patient populations including those with vestibular disorders (Wrisley et al., 2004, Whitney et al., 2004a, Gil-Body et al., 2000). The TUG includes timed walking at speeds required to safely cross a street (Robinett and Vondran, 1988) and the FGA includes complex tasks necessary for functional mobility. Reduced gait speed is associated with reduced functional activity capacity and increased falls risks (Whitney et al., 2004a). The TUG has been shown to be associated with change in physical performance following vestibular rehabilitation in adults with balance and vestibular disorders (Meretta et al., 2006) and difficulty of performing ADLs in older adults (Podsiadlo and Richardson, 1991). Although the TUG assesses gait speed, which is functionally important, it does not assess the quality of performance such as ability to modify gait to task demands or ability to perform other functional activities. Both FGA and TUG are useful as a screening tool to identify potential balance problems and predict falls risk. However they are unable to provide information regarding the underlying balance impairments that limit functional independence.

Given all findings from the current study, a higher level of balance confidence and better functional performance is associated with higher nRMS accelerations which suggesting better postural stability control in patients with a vestibular disorder (uVL). There is no study to date assesses relationship between upper body accelerations during walking with standard clinical scales as well as functional assessments in patients with a peripheral vestibular disorder. These

preliminary findings, findings of the current study suggested that data from accelerometry can be used to assess dynamic functional performance which may be helpful in identifying the underlying balance impairment in patients with a vestibular disorder.

Clinical implication

It has been shown that the majority of patients with peripheral vestibular disorders respond well to rehabilitation but some remain affected by dizziness and imbalance symptoms (Whitney and Sparto, 2011, Herdman et al., 2012). Previous studies have highlighted the impact of vestibular disorders on dynamic locomotion including changes in postural stability and orientation as well as spatio-temporal gait parameters. Unfortunately, most of the assessments were conducted in controlled environment settings and this may not reflect to the actual conditions that patient's balance control usually challenged. Therefore the use of accelerometers as part of clinical tool may provide additional information related to balance control that could not be identified by standard clinical tools. Accelerometers have also been shown to be capable of monitoring changes in trunk acceleration patterns following vestibular rehabilitation in patients with a unilateral vestibular disorder (Wilhelmsen et al., 2010). A study showed that ML RMS acceleration at the upper trunk was reduced while accelerations at the lower trunk increased following vestibular rehabilitation (Wilhelmsen et al., 2010). The authors suggested that the change in the upper trunk attenuation particularly in the ML direction and associated with improved mobility of the lower trunk, indicated better head control as well as increased adaptability of the lower trunk to external demands. These

changes are compatible with improved balance control during walking in patients with unilateral vestibular disorder. This previous finding further supports the potential usage of the accelerometers in assessing balance control during walking and also to measure the effectiveness of treatment in patients with unilateral vestibular disorder. In addition accelerometers are small in size and relatively low cost make it potentially useful to be used to assess a patient's outdoor mobility.

It is noted in this study that ABC scale score is significantly associated with normalised RMS acceleration in patients. Although it is not clear whether reduced acceleration as a result of low balance confidence or impaired postural control directs to poor balance confidence, it is important to acknowledge this relationship. If the former is true, identifying patients with low balance confidence level follows by a proper intervention in treating the confidence level may facilitate to a better postural control.

It is hoped these findings may provide better understanding of dynamic postural stability control in patients with a vestibular disorder and helps to further develop advances in vestibular rehabilitation where optimal treatment strategies remain to be determined.

Conclusion

Current study findings indicate that people with a vestibular disorder employ compensatory mechanisms including reduced walking speed and reduced trunk acceleration to maintain postural stability while mobilising in urban environment. Walk on uneven surfaces further challenged upper body stability particularly in

ML direction in patients. This supports previous reports on the importance of trunk movement to facilitate head stability during walking. Significant correlation has been noted between normalised RMS accelerations and balance confidence, walking duration and some standard clinical assessment tools (i.e. TUG and FGA). Accelerometer could be a useful tool to measure gait and balance impairment particularly in outdoor setting, monitor changes in postural stability while performing dual-tasking, and monitor the effectiveness of interventions in patients with a vestibular impairment.

CHAPTER 3 :EFFECT OF URBAN WALKING ENVIRONMENTS ON POSTURAL CONTROL IN PATIENTS WITH STROKE

3.1 INTRODUCTION

Stroke is a leading cause of disability in the United Kingdom and a primary goal in stroke rehabilitation is to improve walking ability. Post-stroke, sixty to eighty percent of people can walk independently (Kelly-Hayes et al., 2003), but only 50% regain community ambulation (Perry et al., 1995). The majority of people with stroke rate community ambulation as “essential” (Lord et al., 2004) and when limited it has been shown to affect quality of life, level of satisfaction, and mood disorders (Pound et al., 1998). In recent years, studies have begun to identify the factors which are associated with participation in community ambulation after stroke.

Community ambulation requires a person's ability to integrate walking with other tasks such as walk while carrying a shopping bag, in a complex environment. People with chronic stroke report community ambulation as difficult; with factors such as reduced gait speed (Olney and Richards, 1996, Lamontagne et al., 2007b), poor endurance (Eng et al., 2002, Iosa et al., 2012c) and reduced ability to adapt to environmental tasks demands (Said et al., 1999, Lamontagne et al., 2003, Lamontagne et al., 2005b, Lord et al., 2006, Hollands et al., 2010) suggested as contributing factors to this. A recommended gait velocity for safe community ambulation has been suggested depending upon the task performed e.g. walking indoors vs crossing a road and the environment e.g. rural vs. urban where faster gait speeds are crucial for the latter tasks and environments (Shumway-Cook et al., 2002, Robinett and Vondran, 1988). Reduced gait

speed in chronic stroke patients may increase gait instability (Iosa et al., 2012c) and as a consequence increase a person's risk for falls. Fall during walking are commonly reported for this population (Harris et al., 2005).

Walking in urban environment constantly required changes in postural control strategies in order to adapt to the environmental demands such as walking in a crowd, crossing obstacles and roads, avoiding bumping into people and scanning the environment for navigational and safety purposes. Altered orientation and coordination of gaze and body movements during walking and turning post stroke, results in difficulty to execute head motion, turning and steering while walking (Lamontagne et al., 2007a, Lamontagne and Fung, 2009). Reduced ability to step over obstacles successfully; particularly high obstacles has also been noted (Said et al., 1999). Failure to clear obstacles which may, or may not be clearly visible e.g. uneven terrain, holes, bumps during ambulation could provide more challenges to dynamic balance control in people with stroke.

Functional walk tests such as the 6 and 12-Minutes Walk Test (6MWT and 12 MWT respectively) are commonly used in clinical settings to assess walking endurance in patients with stroke (Iosa et al., 2012c, Eng et al., 2002). Outcomes from these functional walk tests mainly focus on walking speed and the distance covered during ambulation which is commonly a short distance indoors setting. Furthermore, these tests do not take into consideration change in gait patterns resulting from environmental (walking on cobbled pathway vs. level ground) and task demands (carrying a shopping bag) which is known crucial for community ambulation following stroke (Lord et al., 2006). Therefore

outcomes of these tests may not reflect a person's actual gait performance in real world situations.

As previously stated accelerometers allow for the measurement of postural stability control during walking in healthy people and in patients with sensory impairment (i.e. vestibular system). In a stroke population, accelerometers have been widely used for assessing physical activities involving the upper and lower extremities. Systematic reviews demonstrate that accelerometry based system is a valid and reliable tool to measure physical activity in stroke survivors (Green, 2007, Gebruers et al., 2010). The system has been used in different settings (indoor and outdoor) and to monitor different stages of stroke rehabilitation (acute or chronic), however limited studies have used accelerometers to evaluate gait stability during walking. A study by Iosa and colleagues (2012c) focused on the effect of prolonged walking on gait stability in stroke. The findings showed a significant reduction in walking speed, walking distance and raw trunk accelerations in people with stroke compared to the healthy group. In addition, stroke patients with different level of walking capability (i.e. walk shorter vs longer distance) demonstrated different walking strategies in which longer- distance walkers maintained their walking speed with their trunk acceleration progressively increasing overtime. This suggests an increase in gait instability over the duration of the walk in patients who walked longer distance. In contrast, those walked at a shorter distance progressively reduced their walking speed without any significant change in trunk acceleration (Iosa et al., 2012c).

Therefore the aim of this study remains to determine upper body stability control, by using accelerometers when walking in real urban environments in

independent, community-dwelling stroke survivors. Furthermore, patients with stroke have been shown to be over-reliant on visual cues for balance (Slaboda et al., 2009). Therefore it was hypothesised that in busy visual environments i.e. walking through a crowded train station where visual cues are inaccurate this patient cohort would experience greater difficulty with regards to healthy control individuals. A secondary aim was to determine the association between accelerometry data and functional abilities, visual dependence and subjective outcome measures in patients with stroke.

3.2 MATERIAL AND METHODS

3.2.1 Subjects

All participants were aged between 18 and 65 years old and independently mobile community dwelling individuals. Participants with history of stroke (Group S) were recruited from members of the Different Strokes charity set up for younger stroke survivors and from other local community support group for patients with stroke in central and southeast London. The inclusion criteria were 1) history of a single stroke; 2) able to independently walk in the community with or without the use of a single-pointed stick. Exclusion criteria were 1) presence of additional neurological condition other than stroke; 2) Other medical problem in acute phase e.g. orthopaedic injury; 3) severe visual impairment (i.e. visual field deficits); 4) Abbreviated Mental test score ≤7 (Hodkinson, 1972).

Healthy individuals (Group C) were recruited via circular email to students and staff members attending King's College London, London, UK. The inclusion criteria were no self-reported history of 1) a balance problem or dizziness; 2) an acute orthopaedic injury; or 3) neurological condition including stroke.

All participants were requested to avoid from taking alcohol 24 hours prior testing. Local ethic committee approval was obtained and informed consent from all participants was obtained after study procedures were fully explained.

3.2.2 Self-report assessments

All participants completed a set of validated questionnaires relating to confidence level, current emotional state and vertigo-related provoking situations prior to completing the urban walking task.

a. The Situational Vertigo Questionnaire (SVQ) (Guerraz et al. 2001) yields a normalized score between 0 (never) to 4 (always) measuring how frequently symptoms are provoked or exacerbated in environments with visual-vestibular conflict or intense visual motion (e.g. walking down a supermarket aisle, watching moving television scenes). Normalised scores >0.7 indicate the presence of visual vertigo symptoms (Pavlou et al. 2006).

b. The Activities Specific Balance Confidence Scale (ABC) assesses confidence level (percentage) a person has in conducting activities of daily living such as bending over, reaching things, indoor and outdoor mobility (i.e. walk around the house, walk outdoor in busy places such as mall and walk on uneven surface such as a ramp, icy sidewalks) without losing balance or becoming unsteady (Powell and Myers, 1995). ABC has been used widely in stroke population (Botner et al., 2005, Salbach et al., 2006, Ng, 2011, Schmid et al., 2012) and has been shown to be a valid and reliable tool for assessing confidence level in performing ADLs for individual with stroke (Botner et al., 2005). Scores range

between 0% (no confident) to 100% (complete confidence). Responses to individual questions are then averaged to get a percentage score, with lower scores indicating less confidence in ADL performance.

c. The Hospital Anxiety and Depression Scale (HADS) (Zigmond and Snaith, 1983) independently measures anxiety (HAD-A) and depression (HAD-D) symptoms. Score range between 0 and 21 for each subscale. The scale has been validated for stroke group and score of 8 and more indicating a significant level of depression or anxiety symptoms (Aben et al., 2002).

3.2.3 Fugl-Meyer Motor function assessment of post-stroke hemiplegic

The Fugl-Meyer Motor Assessment scale (Fugl-Meyer et al.,1975) was used to assess motor function ability. Only Group S participants completed this test. The scale has been validated and shown good reliability for use in a stroke population (Gladstone et al., 2002, Salter et al., 2005). The assessment items include measurement of movement ability (i.e. shoulder, elbow, forearm, wrist, hand, hip, knee, ankle flexion and etc), reflexes and movement speed. Score ranges between 0 (cannot perform) and 2 (perform fully). Total score ranges between 0 (hemiplegic) and 100 points (normal motor performance) and divided into two parts: 1) upper extremity which consists of maximum 66 points and 2) lower extremity maximum points of 34. Each movement was performed on the unaffected side first followed by the affected side.

3.2.4 Objective measures

3.2.4.1 Rod and Disc test

The Rod and Disc test measures perceptual responses for visual dependence. Each participant was instructed to sit upright 80cm, eye levelled, from a disc covered with white dots projected from a screen. A chin rest secured the participant's head position and feet were positioned on a footstool throughout the experiment. Four trials were completed for each disc condition (static disc, clockwise (CW), or counter clockwise (CCW) rotation). Before each trial, participant was asked to close his/her eyes, the disc either static or begins to rotate approximately 30°/s and the rod was tilted approximately 40º, clockwise or counter clockwise, in counterbalanced order and this was randomized between participants for each test condition. Each participant was instructed to adjust the tilted rod to his/her perceived gravitational vertical using a wireless mouse without time constraint. The experiment was conducted in darkness with the only visible object being the rod and dots. All participants completed the static disc condition as a baseline prior to rotational disc conditions. The Rod and Disc software is a customised programmed by Mr. David Buckwell at Imperial College London, U.K. Subjective visual vertical (SVV) was calculated as angular deviations (degrees) of the top of the rod from the true gravitational position (0^0) for each trial. The positive and negative values indicated the direction of disc rotation CW and CCW respectively. The SVV values were recorded automatically by the programme and were saved as a text file.

3.2.4.2 Timed Up and Go (TUG)

The TUG is a simple and quick clinical test that can be used to assess functional mobility in frail elderly including stroke patients (Faria et al., 2012, Ng, 2011, Salbach et al., 2006, Ng and Hui-Chan, 2005, Podsiadlo and Richardson, 1991). TUG has shown excellent interrater (0.91 ≤ICC ≤ 0.95) (Faria et al., 2012, Ng et al., 2005) and intrarater reliability (ICC = 0.75) (Faria et al., 2012) in patients with stroke and TUG also able to discriminate functional mobility between healthy and chronic stroke (Ng et al., 2005). The TUG score was recorded in a unit of 'seconds'.

3.2.4.3 Functional Gait Assessment (FGA)

A ten-item test based on the Dynamic Gait Index (DGI) includes tasks such as walking with head movements, tandem, or backwards. Each item is rated between 0 (severe impairment) and 3 (normal) with a maximum score of 30; higher scores indicate better performance. The FGA has shown to be a valid and reliable tool for patients with stroke with high intrarater (0.95 ≤ICC ≤ 0.97) (Lin et al., 2010, Thieme et al., 2009) and inter-rater reliability (ICC=0.94) (Thieme et al., 2009). The FGA has also shown a moderate responsiveness in detecting changes following rehabilitation in patient with stroke (Lin et al., 2010). A minimal ceiling effect has been noted in FGA as compared to the DGI indicating FGA has the best discriminative ability for stroke patients who are high walking function (Lin et al., 2010).

3.2.5 Urban walking procedures

All participants were instructed to walk at their own comfortable walking speed throughout the urban walking task. The use of a walking aid (i.e. single-pointed walking stick) for Group S participants, as normally applied for the person's mobility routine, was allowed. The procedure for the experimental set-up, urban walking route, data acquisition and processing are followed as under the heading "Urban walking procedures" in Chapter 2 (Sections 2.2.4 to 2.2.6).

3.2.6 Analysis

Statistical analyses were performed using SPSS version 17. For normally distributed data, an independent sample t-test was used to compare between-group differences. For non-normally distributed and ordinal data, a Mann-Whitney U test was performed. One-Way ANOVA was conducted to examine the within-group effect of urban environments on the postural strategies used. Spearman's correlation was performed to investigate the relationship between total acceleration data and self-reported outcome measures (SVQ, ABC, and HAD), Fugl-Meyer scores, objective outcome measures (TUG and FGA) and spatio-temporal variables (gait speed, walking duration and steps) within-groups. Only significant findings were reported in the result section.Significant results for all tests were assumed if $p<0.05$.

3.3 RESULTS

3.3.1 Subject information

Thirty-three subjects participated in this study (Group S=17 and Group C=16). Mean age was 52 years (range: 36-65 years) for Group S and 46 years (range: 26-62 years) for Group C. There was no significant between-groups difference for age ($t(31)=1.67$; $p=0.11$). Full demographic and clinical characteristics of Group S upon recruitment are displayed in Table 6.

Table 6 Table 6 Demographic and clinical characteristics of Group S upon recruitment

Variable	Group S
Age (y) (mean, range)	52 (range: 36-65 years)
Gender,n Male, n (%) Female, n (%)	 64.7% (n=11) 35.3% (n=6)
Time since stroke (month)(mean, range)	41 (4-156)
Fugl-Meyer Scores (mean, range) Upper limb Lower limb	 44 (4-66) 26 (10-34)

3.3.2 Self-reported outcome measures

Significant differences were noted between-groups for all self-report measures. Group S scored significantly lower (i.e worse) on the ABC scale [$z=-4.79$; $p<0.01$] and showed a higher (i.e worse) mean score for non-somatic anxiety

(HAD-A) [z=-2.50; p=0.01], depression (HAD-D) [z=-4.59; p<0.01] and SVQ [z=-1.95; p=0.05] as compared to Group C. Descriptive data for all questionnaire scores are displayed in Table 7. Within-group descriptive data, significant HAD scores were noted in seven and eight of Group S participants for anxiety and depression symptoms respectively. More than half (n=10) of Group S scored ABC less than 67% which indicating of risks for falls. Abnormal SVQ score was noted in five of Group S participants which suggesting of visually vertigo. All Group C participants HAD and ABC score were within normal range and almost all (n=15) had SVQ within normal range.

Table 7 Mean (SD) for self-reported outcome measures

Variable	Group S Mean (SD)	Group C Mean (SD)
HAD-A	7.59 (4.84)	3.44 (2.42)*
HAD-D	7.71 (3.93)	1.00 (1.00)**
ABC	57.77 (25.75)	97.19 (2.53) **
SVQ	0.72 (0.86)	0.28 (0.73) *

Abbreviations: Group S= patients with stroke; Group C= control healthy; SVQ=Situational Vertigo Questionnaire;HAD-A=Hospital Anxiety and Depression (Anxiety scale);HAD-D=Hospital Anxiety and Depression (Depression scale);ABC=The Activities Specific Balance Confidence Scale. The asterisk (*) indicates a significant between-group difference (*p<0.05; **p<0.01)

3.3.3 Objective outcome measures

Significant between-group differences were noted for all objective measures outcomes except RDT static scores. Group S mean scores were significantly lower (i.e. worse) for the FGA [z=-4.88; p<0.01], required a longer time to complete the TUG [t(18)=6.24; p<0.01] and showed greater SVV tilt [z=-1.98; p=0.05] compared to Group C. Mean scores (SD) for FGA, TUG and RDT are shown in Table 8.

3.3.4 Urban gait outcomes

3.3.4.1 Steps, walking duration and gait speed

Significant between-group differences were noted for all gait variables. The time required to complete the urban walking task was significantly longer for Group S [t(18)=5.47; p=0.00] who also took more steps [t(15)=2.18; p=0.05] and had a reduced gait speed in each environmental condition [Colonade: t(26)=-6.13; p<0.01; Dark: t(28)=-6.17; p<0.01; Busy: t(25)=-6.42; p<0.01; Cobbled: t(29)= -5.96; p<0.01; Quiet: t(30)=-5.67; p<0.01]. Descriptive data for walking speed, duration and number of steps taken for each group can be found in Table 8.

Table 8 Mean (SD) values for objective outcome measures and urban gait data

Objective measures	**Group S**	**Group C**
FGA	19.7 (5.85)	29.6 (0.62)**
TUG	13.8 s (3.96)	7.6 s(1.02)**
Static SVV (degrees)	0.15 (1.92)	0.49 (0.59)

Dynamic SVV (degrees)	4.99 (2.82)	3.36 (3.58)*
Urban gait		
Number of steps taken to complete route	1350 (435)	1089 (118.6)*
Walk duration (min.)	21.63 (4.50)	15.2 (1.32)**
Urban walking velocity, ms^{-1}		
Colonade	0.99 (0.28)	1.47 (0.16)**
Dark	1.00 (0.27)	1.50 (0.18)**
Busy	0.95 (0.24)	1.36 (0.12)**
Cobbled	0.97 (0.33)	1.55 (0.22)**
Quiet	1.03 (0.27)	1.50 (0.20)**

Abbreviations: Group C= patients with stroke; Group C= control healthy; FGA=functional gait assessment; TUG=Time up and go; SVV=Subjective visual vertical. The asterisk (*) denotes a significant between-group difference (*p<0.05; **p<0.01)

3.3.5 Acceleration patterns

3.3.5.1 Overall acceleration patterns

Normalised RMS acceleration (nRMS) patterns for the head, neck and trunk across the five environmental conditions for both groups are illustrated in Figure 13. Greater AP head nRMS was noted in Group S compared to Group C [APHead: Colonade: t(31)= 2.25 p=0.03; Dark t(31)= 2.24 p=0.03; Busy t(31)= 2.14 p=0.04; Cobbled t(31)= 3.51 p=0.00; Quiet t(31)= 3.10 p=0.00]. Reduced head nRMS was noted in the V direction for Group S compared to Group C

[VHead: Colonade t(31)= -5.78 p=0.00; Dark t(31)= -5.84 p=0.00; Busy t(31)=-6.75 p=0.00; Cobbled t(31)= -6.36 p=0.00; Quiet t(31)= -5.46 p=0.00].

At neck level, mean nRMS in V directions were significantly smaller for Group S compared to Group C in all environmental conditions [Colonade t(31)= -5.72 p=0.00; Dark t(31)= -5.61 p=0.00; Busy t(31)=-6.31 p=0.00; Cobbled t(31)= -5.76 p=0.00; Quiet t(31)= -5.27 p=0.00]. Smaller AP neck nRMS was noted in 'busy' [t(31)=-2.29 p=0.03] and 'cobbled' [t(31)=-2.63 p=0.01] conditions.

Group S demonstrated smaller trunk V and AP nRMS compared to healthy controls (Group C) for all environment conditions [APTrunk: Colonade t(31)= -6.08 p=0.00; Dark t(31)= -6.28 p=0.00; Busy t(31)=-6.98 p=0.00; cobbled AP t(31)=-6.17 p=0.00; Quiet t(31)= -6.00 p=0.00 and VTrunk: Colonade t(31)= -5.37 p=0.00; Dark t(31)= -5.32 p=0.00; Busy t(31)=-5.97 p=0.00; Cobbled t(31)=-5.68 p=0.00; Quiet t(31)= -4.99 p=0.00]. Reduced trunk nRMS was also noted in the ML direction for Group S, particularly in the cobbled environmental condition [Trunk Cobbled: ML t(31)=-2.67 p=0.01]. Between-group mean differences of RMS accelerations at the head, neck and trunk levels are displayed in Table 9 with a negative value indicating a reduction of acceleration values for Group S.

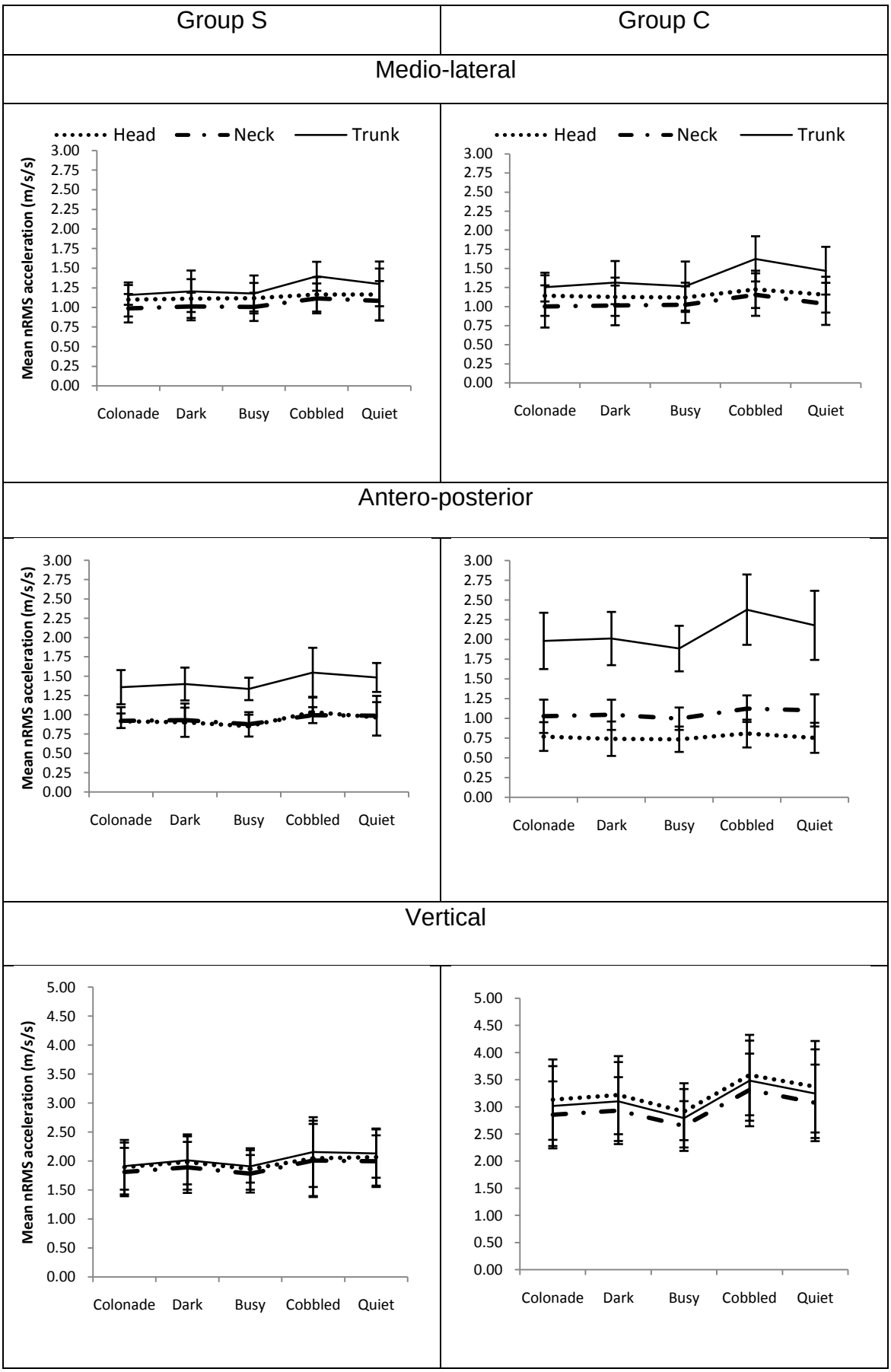


Figure 13 Accelerations patterns at the head, neck and trunk levels across the five environmental conditions.

Abbreviation: nRMS=normalised accelerations RMS.

Table 9 Mean difference between groups (△ for nRMS accelerations at the head, neck and trunk.

		△ nRMS accelerations				
	Level	Environmental condition				
		Colonade	Dark	Busy	Cobbled	Quiet
ML	Head	-0.04	-0.02	0.00	-0.06	0.01
		(0.08)	(0.09)	(0.07)	(0.08)	(0.10)
	Neck	-0.01	0.00	-0.02	-0.04	0.05
		(0.08)	(0.08)	(0.07)	(0.08)	(0.09)
	Trunk	-0.10	-0.11	-0.09	-0.23**	-0.17
		(0.06)	(0.10)	(0.10)	(0.09)	(0.10)
AP	Head	0.14 *	0.16*	0.12*	0.23**	0.21**
		(0.06)	(0.07)	(0.05)	(0.07)	(0.07)
	Neck	-0.10	-0.12	-0.12*	-0.13**	-0.11
		(0.06)	(0.07)	(0.05)	(0.05)	(0.08)
	Trunk	-0.62**	-0.61**	-0.55**	-0.83**	-0.69**
		(0.10)	(0.10)	(0.08)	(0.13)	(0.12)
V	Head	-1.24**	-1.23**	-1.05**	-1.54**	-1.30**
		(0.21)	(0.21)	(0.16)	(0.24)	(0.24)
	Neck	-1.04**	-1.04**	-0.87**	-1.30**	-1.08**
		(0.18)	(0.19)	(0.14)	(0.23)	(0.20)
	Trunk	-1.10**	-1.09**	-0.88**	-1.33**	-1.12**
		(0.21)	(0.20)	(0.15)	(0.23)	(0.22)

The negative values indicate the nRMS was smaller in patients group as compared to healthy control group. Abbreviations: nRMS= the difference of mean normalised RMS accelerations between groups; ML = medio-lateral; AP = antero-posterior; V=vertical. The asterisk (*) denotes significant between-group difference (* $p < 0.05$; ** $p < 0.01$)

3.3.5.2 Effect of environmental conditions on within-group RMS accelerations.

A significant effect of environmental condition on nRMS head acceleration was only noted for Group S with post-hoc tests revealing a significantly greater AP acceleration in the 'cobbled' compared to 'busy' environmental condition ($F(4,80)=2.43$ $p=0.05$).

A significant effect of environmental conditions on neck acceleration was noted only for Group C with post-hoc test revealed a significantly increment in vertical acceleration in the 'cobbled' compared to the 'busy' environmental condition ($F(4,80)=0.88$ $p=0.48$).

For both groups, RMS trunk acceleration in both ML and AP directions significantly varied with environmental conditions [Group S: ML:$F(4,80)=3.30$ $p=0.02$; AP:$F(4,80)=2.62$ $p=0.04$; Group C: ML: $F(4,75)=4.96$ $p=0.00$; AP: $F(4,75)=4.22$ $p=0.00$]. For Group C, trunk acceleration in both ML and AP directions was significantly greater in 'cobbled' compared to 'colonade' and 'busy' environmental conditions. For Group S, post-hoc analysis revealed significant different between environments in the ML direction only. Figure 14, 15 & 16 illustrate within-group effect of environmental conditions for each direction.

Medio-lateral

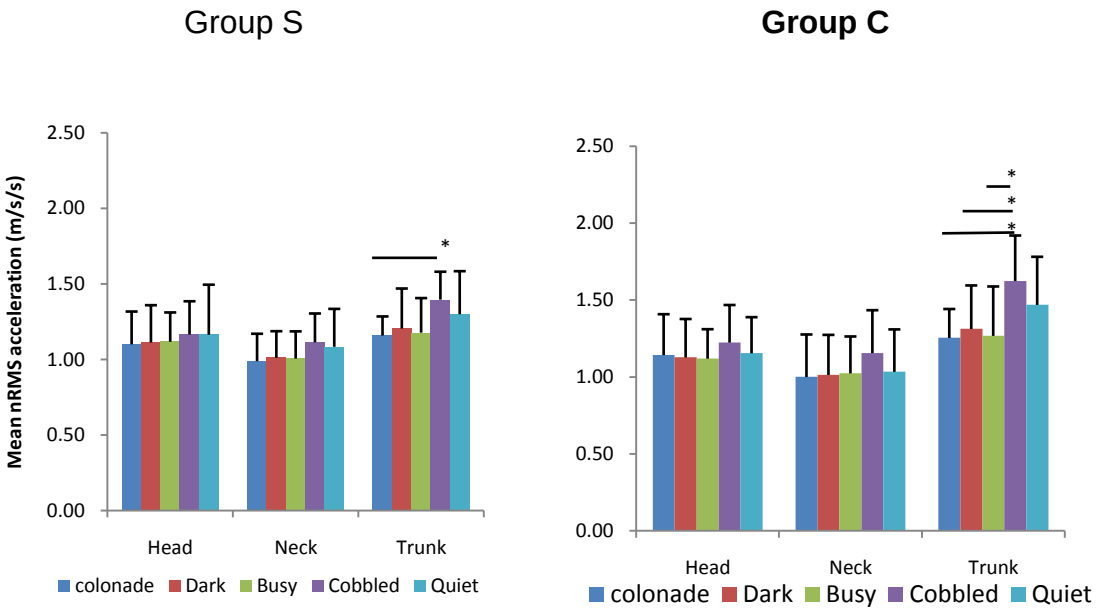


Figure 14 Effect of environmental conditions on ML nRMS acceleration at head, neck and trunk.

Antero-Posterior

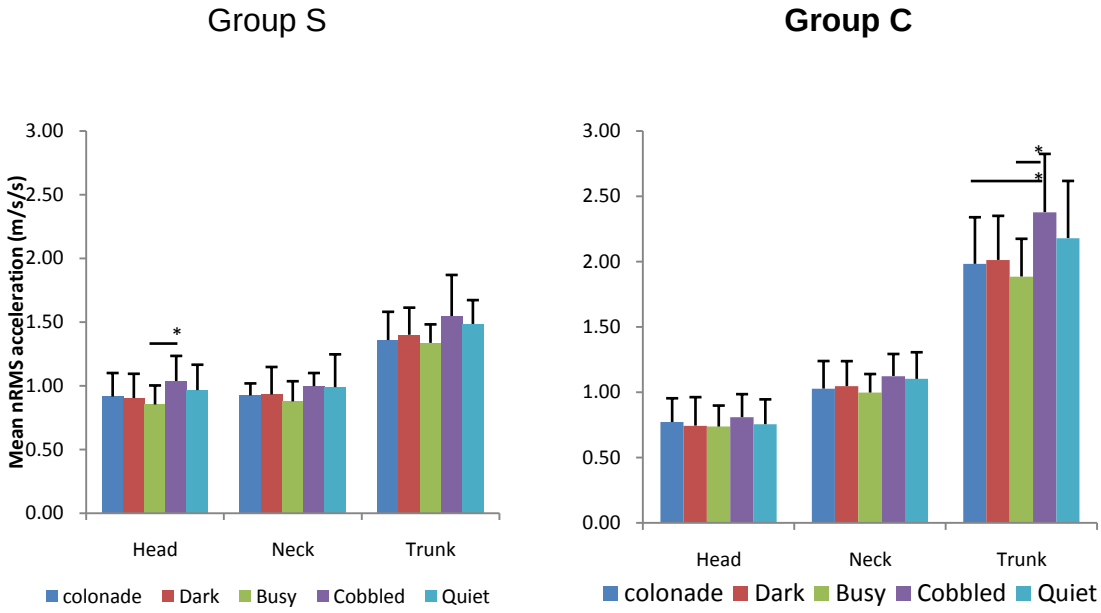


Figure 15 Effect of environmental conditions on AP nRMS acceleration at head, neck and trunk.

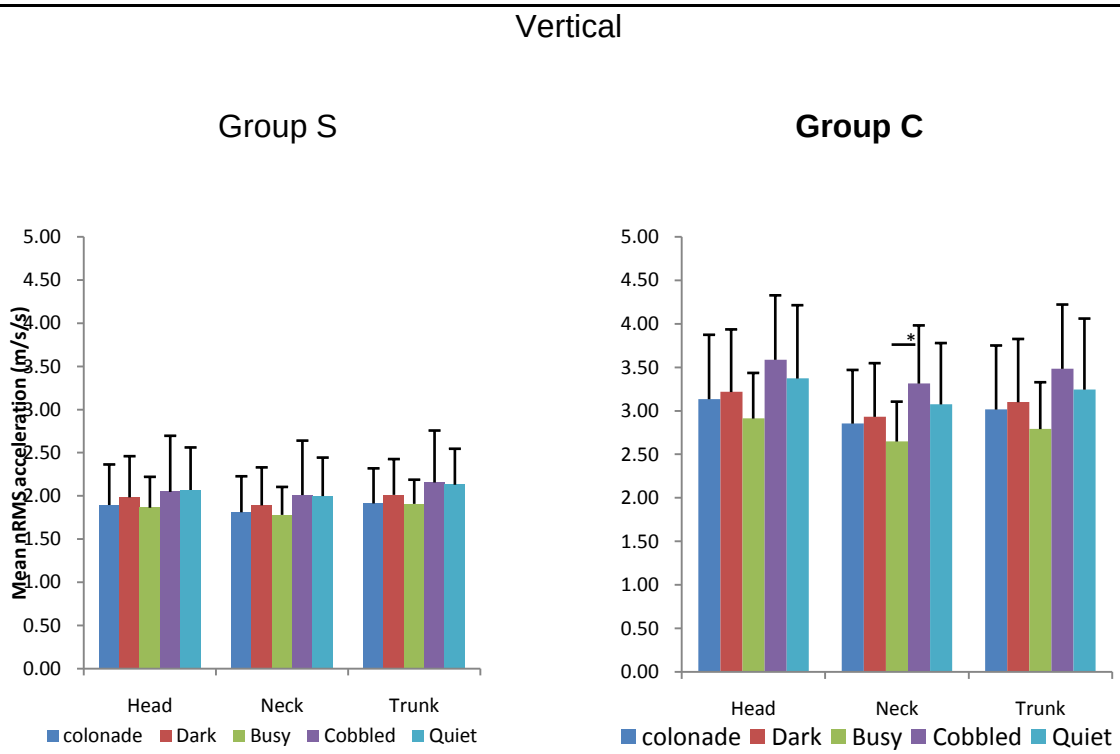


Figure 16 Effect of environmental conditions on within-group V nRMS acceleration at head, neck and trunk.

Abbreviation:nRMS=normalised accelerations RMS. The asterisk (*) indicates significant between-environmental condition difference.

3.3.7 Association between mean total accelerations and gait spatio-temporal parameters.

Figure 17 shows the relationship between the mean total preferred walking speed and the mean total raw accelerations and nRMS accelerations in both groups. For Group C, significant positive correlations were noted between the mean total raw accelerations RMS in AP and V direction and the mean walking speed (AP: r=0.85; p=0.00 and V: r= 0.89; p=0.00). A significant correlation was also noted between the normalised accelerations (nRMS) in all directions and the walking speed (ML: r=0.57; p=0.21; AP: r=0.94; p=0.00 and V: r= 1; p=0.00) for Group C. For Group S, the mean walking speed was significantly correlated with mean total raw accelerations (AP:r=0.62; p=0.01 and V : r=0.87;p=0.00) and nRMS (AP: r=0.70; p=0.00 and V : r=1;p=0.00) both in AP and V directions. Age was not significantly correlated either with mean total raw accelerations RMS or mean total nRMS accelerations in any direction for both groups ($p>0.05$).

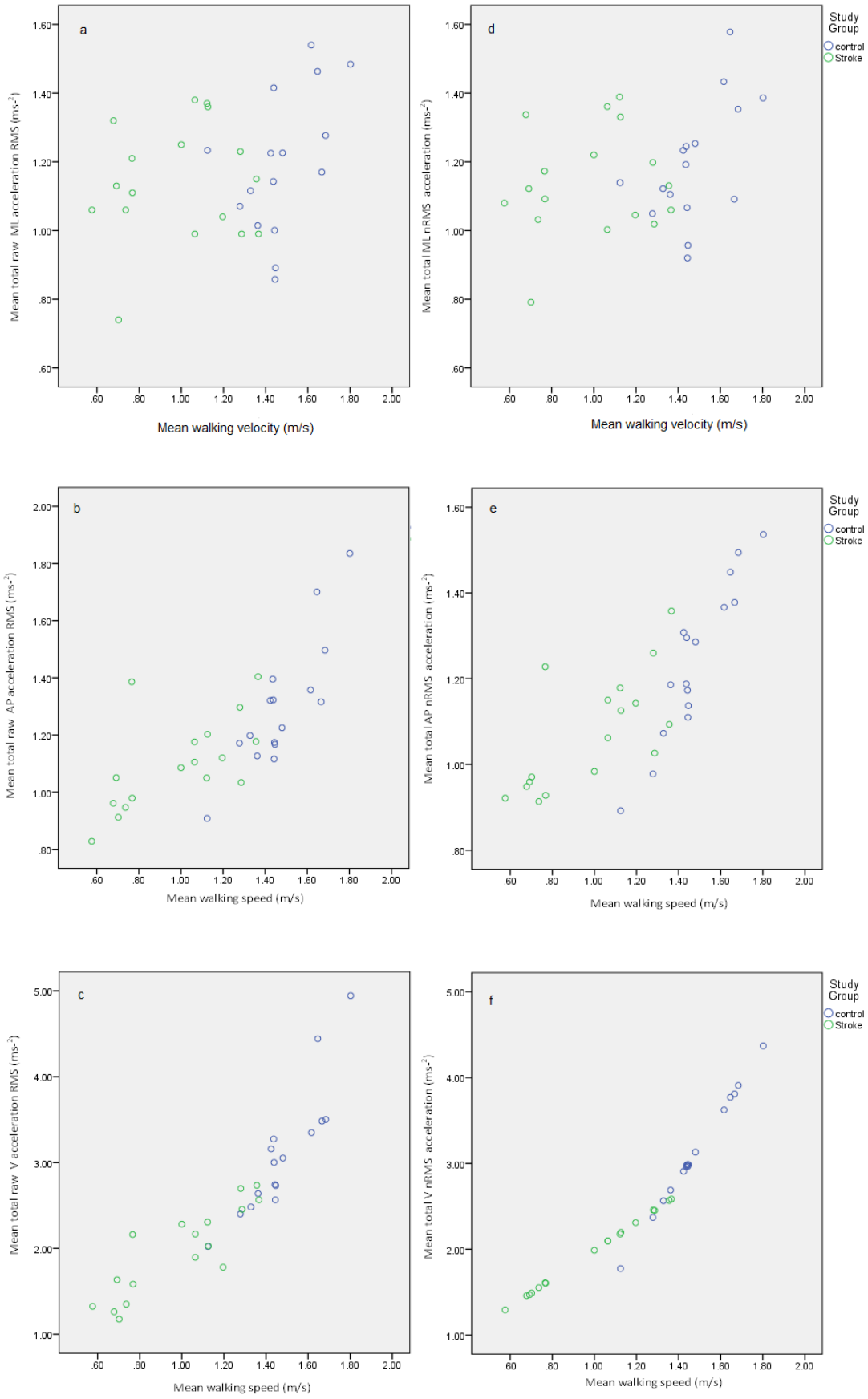


Figure 17 Scatterplot showing the relationship between gait speed and RMS accelerations data

The effect of walking speed on the mean total raw accelerations RMS in ML (a), AP (b) and V (c) directions and the mean total normalised accelerations (nRMS) in ML (d), AP (e) and V (f) directions.

In both groups, a shorter total walk duration and smaller number of steps taken to complete the walking task significantly correlated with a greater nRMS acceleration in V direction [Group S: Steps r=-0.72; Duration=-0.88 p=0.00; Group C: Steps r=-0.60 p=0.01; Duration r=-0.74 p=0.00].

3.3.8 Correlation between mean total nRMS accelerations and objective and subjective outcome measures in patients group.

A significant positive correlation was noted between Fugl-Meyer scores and total nRMS accelerations particularly in the AP and V directions. Higher Fugl-Meyer scores (i.e. better performance) were associated with greater total RMS accelerations [Fugl-Meyer upper limb: AP r=0.61 p=0.01; V r=0.69 p=0.00 and Fugl-Meyer lower limb: AP r=0.55 p=0.03; V r=0.72 p=0.00]. Lower TUG (i.e. better) scores significantly correlated with higher vertical nRMS accelerations (r= -0.79; p=0.00). No subjective outcome measures significantly correlated with mean total nRMS (p>0.05).

3.4 DISCUSSION

Vertical head, neck and trunk nRMS was significantly smaller in Group S compared to the age-matched healthy control group. Greater head and smaller AP trunk nRMS were also noted in Group S. Overall, the healthy group maintained head stability by modulating trunk coordination while navigating in an urban environment. Mobilising on an uneven surface had the greatest effect and induced head instability particularly in the AP direction (the direction of progression) in patients with stroke (Group S).

The following discussion is separated into the following sections: (a) Gait pattern changes; b) Postural stability during walking in an urban environment; (c) the relationship between urban walking and standard clinical scales and assessments (d) Clinical implications.

A) Gait pattern changes

Findings of the current study showed that patients with stroke walked at a slower speed, took more time and more steps to complete the urban walking task than the age-matched control individuals. Although no statistical comparison was made between two pathological groups (stroke vs vestibular impairment (finding from Chapter 2)), it was noted that patients with stroke walked at a slower rate compared to the latter group. Our results agree with previous findings showing impaired gait parameters (i.e. gait speed, ambulation duration) following stroke (Sibley et al., 2009, Mizuike et al., 2009, Iosa et al., 2012b, Iosa et al., 2012c).

Some researchers (Perry et al., 1995, Hill et al., 1997) have found a correlation between gait velocity and community ambulation in patients with stroke while others do not (Lord et al., 2004). A recent study found that gait velocity,

balance, and physical factors of the hemiparetic limb, including lower limb strength, explained only a small amount of the variance for community ambulation (Robinson et al., 2011). There was also no association noted between participation and ability on complex walking tasks performed in a laboratory setting (Robinson et al., 2011). However this is different to being able to navigate complex environments and adapt gait according to environmental (walking on cobbled pathway vs. level ground) and task demands (carrying a shopping bag) which is crucial for community ambulation following stroke (Lord et al., 2006, Patla, 2001, Perry et al., 1995).

Robinett and Vondran data (1988) showed that walking in urban environments (i.e. cities with a population size > 95 000) requires faster gait speed and ability to walk longer distances compared to rural or small towns. One of the requirements for safe community ambulation is gait velocity of at least 0.8m/s. A person with chronic stroke who walks less than 0.80m/s in a clinical setting has been shown to have difficulties in navigating slopes and busy environments (supermarket) during community ambulation (Taylor et al., 2006). In the present study gait velocity for people with stroke ranged from 0.95 to 1.03 m/s and this is slower than gait speed (i.e. ranged between 1.23 and 1.35 m/s) recorded from people with vestibular disorder (Chapter 2). This range in gait speed may not be sufficient for person with stroke to safely negotiate an intersection crossing before the signal change, as crossing times are based on a minimum gait speed of 1.2 m/s (Bohannon et al., 2011). Following stroke, gait speed is dependent upon several underlying factors, of which diminished aerobic endurance and lower limb muscle strength have been shown to be major contributors to reduced gait speed in chronic stroke (Taylor-Piliae et al., 2012).

All people with stroke in the current study were able to complete the determined walking routes, however duration to complete the walking rout and number of steps taken were significantly longer time and greater, respectively compared to the healthy controls.

B) Postural control strategies in urban walking

Vertical head, neck and trunk nRMS accelerations, were significantly smaller in Group S (stroke) compared to the age-matched healthy group. Greater head and smaller AP trunk accelerations were also noted in stroke patients. Walking on uneven surfaces had the greatest effect, and induced head instability particularly in the AP direction in patients. Overall, the healthy group maintained head stability by modulating trunk coordination while navigating in urban environments.

Studies incorporating accelerometers to assess upper body stability during level walking in patients with stroke revealed various outcomes (Iosa et al., 2012a, Iosa et al., 2012b; Mizuike et al., 2009) depending on post-stroke stage (sub-acute or chronic). A significant reduction of normalized trunk accelerations and harmonic ratios (implies stable, regular and rhythmic acceleration patterns) in AP and V directions has been noted in patients with sub-acute stroke in comparison to age-matched healthy individuals (Iosa et al., 2012a). Another study showed that normalised RMS trunk acceleration was significantly greater in all three directions in patients with chronic stroke compared to age-matched healthy individuals (Mizuike et al., 2009). An increase in trunk acceleration is associated with smoother or better dynamic gait stability (Iosa et al., 2012b),

reflecting motor system recovery and gait capability in stroke (Mizuike et al., 2009).

It is known that trunk control plays an important role in attenuating gait-related accelerations, as evidenced by low amplitude accelerations at the head compared to lower trunk during gait, to facilitate head and upright stability during walking (Kavanagh et al., 2006). During walking, heel-strike and push-off cause the upper body to oscillate backward and forward (unstable) due to changes in hip acceleration. Backward hip acceleration (at heel-strike) due to ground reaction force causes the upper body to lean forward and forward hip acceleration (at push-off) causes the upper body to lean backwards (Winter 1995). Therefore to overcome upper body instability, counterbalancing torque around the hip and trunk has to be generated to prevent the upper body from falling forward or backward (Woollacott and Tang, 1997). It is known that lower extremity joints produce systematic kinematic changes during the swing and stance phases of the gait cycle that help stabilise the upper extremity (Ratcliffe and Holt, 1997). However changes in kinematic and kinetic parameters including muscle weakness, abnormal timing and amplitude of muscle activation, altered joint movement and coordination, impaired anticipatory postural control have been shown following stroke which may impact on gait parameters and stability (Lamontagne et al., 2003, Lamontagne et al., 2005a, Lamontagne et al., 2007a). Fore-aft stability is achieved through somatosensory feedback from the limbs to the spinal cord which is important for body weight support, energy supply and stability control in the plane of progression during walking (Bauby and Kuo, 2000). These impairments may suggest possible reasons why patients with stroke have difficulty maintaining head stability in the AP direction while navigating in an urban environment.

The effect of different urban walking environment on accelerations pattern of the head, neck and trunk during walking was also investigated in each experimental group. It was predicted in the current study that people with stroke may experience greater difficulty when walking in a busy environment compared to other walking environments i.e. dark, colonade, quiet and cobbled street. This was based on evidence that showed people with stroke are over-reliant on visual cues for balance (Slaboda et al., 2009). Therefore in busy visual environments, such as walking through a crowded train station where visual cues are inaccurate, it was expected that person with stroke would experience greater difficulty. However no significant effect of busy environment was noted in the current study. Few possibilities that could explain our findings. First, time of day testing was conducted which avoided peak times. This precaution was taken to avoid unnecessary disruption to a traffic flow of commuters within the busy area i.e. train station at peak times. Second, patient cohort in the current study may not be visually dependent as shown on their low visual dependency scores. Previous study reported on a significant dynamic subjective visual vertical (SVV) deviation (>10^{o}) in respect to rod and frame test (RFT) in people with stroke (Slaboda et al., 2009). Lack of clinical normative value and homogeneity in experimental settings such as different characteristics of stroke or assessment tools (i.e. RDT, RFT) will make comparison between studies less reliable. Further work is required to investigate the effect of visual dependency on postural stability control during community ambulation in a larger study of people with stroke.

Similar to findings in Chapter 2 investigating urban walking in people with a vestibular disorder, walking on a cobbled street provided greater challenges to postural stability in people with stroke. People with stroke experienced greater

AP head acceleration. A possible cause of the head instability could be attributed to reduced flexibility of the lower limbs due to muscle weakness muscle weakness observed during gait (Jonkers et al., 2009). This limitation may lead to limb clearance difficulties(Jonkers et al., 2009), and potentially threat postural stability, particularly when dealing with unpredictable perturbations resulting from uneven terrain. Higher accelerations at the head may increased optic flow which reduces the effectiveness of vestibular system (Bethoz and Pozzo, 1994) and therefore may lead to an increased instability and likelihood for falls.

C) Relationship between urban walking and standard clinical scales and assessments

The current study found that higher normalised acceleration in V direction was associated with faster gait speed (i.e. reduced TUG scores and walking duration), less number of steps and better motor performance of both the lower and upper limbs as measured by Fugl-Meyer test (FM). No significant correlations were noted between the FGA, RDT, and subjective outcome measures with total acceleration in any direction. These findings suggest that standard clinical test i.e. TUG and FM affects directly RMS accelerations in people with stroke.

The TUG is a commonly used clinical tool to assess functional ability and falls risk, respectively,, in older adults including those with stroke. A significant associations between lower limb muscles weakness, gait speed, some gait parameters (i.e. step length), distance walked and TUG scores have been observed in patients with stroke (Ng and Hui-Chan, 2005, Faria et al., 2009). It

has been suggested that factors including cardiovascular performance, muscle strength, balance impairment and spasticity influence the gait speed and walked distance as indirectly measured in TUG. Contribution of lower limb motor function to gait pattern parameters such as gait speed and trunk acceleration has also been explored in people with stroke (Lin, 2005, Mizuike et al., 2009). A greater motor function recovery of the lower extremities was associated with better gait performance and greater trunk acceleration, thus providing postural stability during walking in people with stroke. Current findings are in agreement with previous work showing a significant relationship between increased gait speed (i.e. TUG) or lower limb range of motion and strength (i.e. FMA) with greater total acceleration in the direction of progression and vertically.

A significant correlation was noted between functional gait assessment (FGA) and accelerometry data in people with a vestibular impairment (Chapter 2) however a significant finding was not noted in people with stroke. The FGA was mainly designed to assess balance and gait problem associated with vestibular disorders, although the use of the test has been extended to other patient population (Lin et al., 2010, Thieme et al., 2009). There is a possibility that tasks assessed in the FGA could not detect subtle change in balance control mechanism during walking in people with chronic stroke, in specific those with a higher functioning level. Therefore future work on this should include people with stroke at various functioning levels such as a non-community dwelling individual (low functioning level).

There is no study to date that assesses the relationship between upper body accelerations during walking in real-life environments with standard clinical scales, as well as functional assessments in patients with chronic stroke. These

preliminary findings, could suggest the usefulness of TUG and Fugl-Meyer tests in predicting dynamic postural control in chronic stroke patients in real, uncontrolled environments where most patient's mobilise and where their capability is challenged.

D) Clinical implication

Impairments in balance and gait coordination have been well documented following stroke, with higher severity usually observed during the acute stage. However, some impairments in balance and gait coordination persist within the chronic stage. Deficits in gait coordination; such as altered temporal and spatial coordination between the head, trunk and pelvis, impaired pelvic, knee and ankle control during the gait cycle, and poor interlimb coordination such as asymmetries in propulsive forces between paretic and non-paretic limbs, step length and width have been documented in chronic stroke survivors despite receiving rehabilitation. As a consequence, these deficits may lead to overall reduction in gait performance e.g. walking speed and endurance among community ambulatory stroke survivors.

The selection of an appropriate outcome measure is crucial to precisely assess walking ability for adults with stroke to help determine the rehabilitation provided to patients. A wide range of walking tests are available to assess 1) walking distance such as Two minute walk test (2minWT), 2) functional ambulation for example Functional Gait Assessment (FGA); and (iv) Walking on different surfaces such as the Six metre Walk Test on parquet and carpe (6mWTPC) (Mudge and Stott, 2007, van Bloemendaal et al., 2012). However the most frequently used clinical walking tests are limited to a short distance walk (<1km as described in The international Classification of Functioning, Disability and

Health (ICF) framework) and are conducted in a well controlled environment e.g. laboratory (Mudge and Stott, 2007). These may not reflect the actual performance of stroke survivors during community ambulation which commonly requires patients to walk longer distances, around obstacles and over uneven ground and navigate around outside or inside buildings (e.g. shopping mall, shops).

The current findings showed that accelerometers can be used to determine postural stability control in a real-world environments and are able to distinguish walking patterns between healthy adults and patients with chronic stroke in addition to patients with unilateral vestibular impairment (Chapter 2). It is suggested that the differences in upper body stability control observed in patients with chronic stroke compared to healthy may possibly be due to impairment in the neuro-muscular-skeletal systems. While in patients with vestibular disorders, gait pattern differences noted may possibly occur as a strategy used to reduce the impact of gait related oscillation on the head, which could further impair gaze stability during walking. This information may be missed if using standard clinical outcome measures and therefore lead to different management strategies that may not tackle the important elements required to improve independent community ambulation among patients.

There is evidence on the influence of gait analysis data on clinical decision-making in the management of post-stroke patients (Ferrarin et al., 2015). In the study (Ferrarin et. al., 2015) gait analysis data (including non-wearable 3D gait analysis system, force plate and EMG) in addition to standard clinical evaluation tools, were used as part of intervention planning. The study found that clinical recommendations made by clinicians who incorporated gait analysis data were

significantly different from those who used only clinical examination and visual observation gait analysis during the ongoing treatment care for stroke. Change in treatment planning i.e. surgical vs non-surgical was also noted in 71% of the studied population i.e. chronic stroke patients when gait analysis data is used by clinicians to facilitate therapeutic planning (Ferrarin et. al., 2015). Thus the authors suggested that the analysis of gait data provides additional information that improved decision-making with regards to chronic stroke care among clinicians. This finding might support the potential use of accelerometry data which is more convenient to be used i.e. less complicated instruments compared to a standard non-wearable 3D gait analysis system, in clinical settings.

E) Conclusion

Current study findings indicate that people with a stroke employ compensatory mechanisms including a reduced walking speed and reduced trunk accelerations to maintain postural stability during gait in an urban environment. However greater AP head accelerations were noted in patients, indicating patients may have difficulty stabilising their head in space compared to a healthy control group. Mobilising on an uneven surfac had greatest effect on postural stability and induced head instability particularly in the AP direction (the direction of progression) in patients with stroke. A significant correlation was noted between accelerometry data and the TUG and FMA indicating accelerometers could be a useful tool to measure gait parameters especially in outdoor settings, monitor changes in postural stability control following stroke and the effectiveness of stroke rehabilitation with regards to functional mobility.

CHAPTER 4: ILLNESS BEHAVIOUR IN PATIENTS WITH VESTIBULAR DISORDER

4.1 INTRODUCTION

An average of 38% of patients with a vestibular disorder carry a risk of psychiatric or psychological disorders (Eckhardt-Henn et al., 2003). Psychiatric co-morbidity such as anxiety, phobic disorders and depression have been found to be greater in patients with vestibular migraine or Meniere's Disease compared to other groups (i.e. vestibular neuritis or BPPV) (Eckhardt-Henn et al., 2008, Tschan et al., 2011). Possible explanation was due to the unpredictable, more severe and uncontrollable nature of attacks in vestibular migraine and Meniere's Disease compared to the other vestibular disorder subgroups (Tschan et al., 2011).

Godemann et al. (2005) found a strong correlation between dizzy symptoms and anxiety in 1/3 of patients who continue to experience symptoms one year post onset.A one year follow-up study on patients with peripheral vestibular impairment showed that patients with high levels of subjective well-being were less likely to develop secondary somatoform vertigo and dizziness (SSVD), whereas SSVD was commonly correlated with individuals with depressive and anxiety disorders (Tschan et al., 2011). The study also demonstrated that SSVD was more prevalent in patients with vestibular migraine compared to other vestibular impairment subgroup (i.e. vestibular neuritis) and those with vestibular migraine experience greater level of disability (Tschan et al., 2011). This has led to a suggestion that psychiatric disturbance may be more associated with certain subgroups of vestibular disorders.

The relationship between vestibular disorders and psychiatric disorders has been thought as bidirectional: a vestibular disorder may trigger a psychiatric disorder (Jacob and Furman, 2001) while a psychiatric disorder may trigger symptoms of vertigo and dizziness (Yardley et al., 2001b, Staab and Ruckenstein, 2003). However, some studies report no relationship between the presence of a vestibular deficit and the development of a secondary psychiatric disorder (Best et al., 2006; 2009).

Since not all patients with vestibular dysfunction develop a psychiatric disorder, this suggests that the underlying causes of illness behaviour is multi-factorial and that some individuals may have traits that make them more vulnerable. An examination of patients' illness behaviour and its association with vestibular dysfunction may provide a critical way in better understanding and identifying the factors that may predispose certain individuals to anxiety disorders and chronic dizziness. Screening for co morbidities such as anxiety and depression offers psychological interventions that are important for patients treatment plan (i.e. patients education).

Illness behaviour has been described as the way an individual responds to a perceived health threat or illness (Mechanic, 1986). It embraces the ways in which people attend to somatic information, interpret and responds to symptoms, and seek medical care. There is substantial interindividual variability of illness behaviour although the symptoms may objectively share comparable characteristics (Mechanic, 1986). Many factors attribute to the illness behaviour including past illness behaviour, coping competency, psychological states, beliefs and personality traits/attitudes.

The term *abnormal illness behaviour* is used to describe a persistent inappropriate or maladaptive response to an underlying organic pathology. This maladaptive behaviour can manifest in a form of illness denial or somatisation of psychogenic disorders (Pilowsky and Spence, 1994). When abnormal illness behaviour comorbid with psychological distress such as anxiety or depression, exacerbation in physical symptoms, functional impairment and impede recovery in patients has been observed in clinical setting (De Waal et al., 2004; Clark and Smith 1997). Abnormal illness behaviour is suspected when individuals show excessive concern about their illness with somatic symptoms and when inappropriate treatment is sought. It is usually associated with absence of organic pathology that would account for the person's physical complaint (Guo et al., 2001). Furthermore abnormal illness behaviour could increase socioeconomic burdens such as increased dependence on others (i.e. doctors, family members), sick role, relief from social responsibilities and avoidance of physical demands (Prior and Bond 2008).

The high prevalence of the comorbidity of psychiatric disorders and the symptoms of vestibular dysfunction (even in the absence of physical deficits) has been well documented. This combination is highly likely to aggravate the illness impact and levels of handicap (EckhardtHennet al. 2003). In addition, abnormal illness behaviour has been reported in patients with Menier's diesease (Savastano et al., 1996). Abnormal illness behaviour may be a contributing factor to the unexplained physical/subjective symptoms and long term handicap observed in some patients with vestibular impairment. Despite these clear links there is a lack of research focussing on the issue of illness behaviour in patients with vestibular impairment. Study on illness behaviour may provide a better insight on this patients population.

Therefore the purpose of this study was 1) to describe the illness behaviour profile in patients with chronic vestibular symptoms 2) to investigate the effect of migraine on the illness behaviour profile and 3) to assess the relationship between illness behaviour, functional gait, postural control and subjective symptoms. It was hypothesised that patients particularly those with migraine may show different illness behaviour pattern from the age-matched control group.

4.2 MATERIAL AND METHODS

4.2.1 Subjects

One hundred and ten participants were recruited into the study in which 77 were patients (Group P) and 33 age-matched healthy control participants (Group C).All participant were aged between 18 and 80 years old. Five patients declined to complete the set of given questionnaire after a written consent was obtained therefore the data from only 72 patients were taken into account in the analysis. Two participant groups were recruited:

- Patients with a diagnosed vestibular disorder or vestibular migraine (Group P)were recruited from outpatient clinics at the Department of Neuro-otology National Hospital for Neurology and Neurosurgery, Queen Square, London. All patients had completed routine audio-vestibular investigations performed by a senior audiologist prior to the recruitment. The routine audio-vestibular investigations include otoscopic examination, tympnanometry test, pure tone audiometry, bithermal caloric test (either videonystagmography (VNG) or Fitzgerald-Hallpike with optic fixation technique) and electronystagmography. Departmental norms were used for significant canal paresis and directional

preponderance. A significant canal paresis was either based on Fitzgerald-Hallpike caloric testing as measured by the duration parameter using the Jongkee's formula of more than 8% in the absence of the optic fixation or ≥20% on VNG bithermal caloric. For directional preponderance, 12% for Fitzgerald-Hallpike or 20% for VNG are the normal values. Diagnosis (or exclusion) of vestibular disorders or vestibular migraine was based upon review of the history, clinical assessment, caloric and ENG data by the attendant consultant neuro-otologist. Inclusion criteria were no other chronic medical/health problems (i.e. orthopaedic injury) which would impact on ability to perform balance and gait assessment and patient was able to walk independently. Patients with central vestibular disorder other than vestibular migraine, current participation in or previous completion of a vestibular rehabilitation programme and/or anti migraine prophalaxis (i.e. in the case of vestibular migraine) were excluded.

- Healthy adults (Group C) were recruited via circular email to students and member of staff at King's College London, London, UK. The inclusion criteria were no self-reported history of vestibular or neurological disease, dizziness, balance disorder, migraine or any acute orthopaedic injury which would impact on ability to perform balance and gait assessment.

Local ethic committee approval was obtained. Demographic data and clinical characteristics of participants' groups are displayed in Table 10.

Table 10 The demographic characteristics of participants upon recruitment.

Variable	Group C (n=33)	Group P (n=72)	
		Without migraine (n=34)	Migraine (n=38)
Age, mean (range),y	43 (18-71)	47 (26-76)	45 (18-72)
Gender Male, n (%) Female, n (%)	 16 (48) 17 (52)	 11 (32) 23 (67)	 10 (26) 28 (73)
Symptoms duration (months) , mean range	Not applicable	38 (3-180)	45 (3-228)
Vestibular findings, n CP BPPV BVH VN No abnormal findings	 Not applicable	 22 3 1 8 0	 13 0 1 0 24

Abbreviations: Group C= control group; Group P= patients with chronic dizziness; CP=canal paresis either based on Fitzgerald - Hallpike caloric testing as measured by the duration parameter using the Jongkees formula of more than 8% in the absence of optic fixation or ≥20 % asymmetry for video-nystagmography; DP = directional preponderance either ≥ 12% based on

Fitzgerald - Hallpike caloric testing or ≥ 20 % asymmetry for video-nystagmography; BPPV= Benign Paroxysmal Positional Vertigo;BVH = Bilateral vestibular hypofunction based on caloric and/or electronystagmography (ENG) findings; VN=vestibular neuritis

4.2.2 Self-report assessments

All participants completed a set of validated questionnaires relating to dizziness symptoms, impact of symptoms on ADL, balance confidence on conducting ADL and impact on global level of function and independence, anxiety and depression experienced within the last month prior to the recruitment. Five questionnaires i.e. SVQ, ABC, HADS, VADL and VSS used in this study have previously beendescribed in Chapter 2 (section 2.2.2). Two additional questionnaires used for the current study are:

a. The Dizziness Handicap Inventory (DHI) (Jacobson and Newman, 1990) is a 25 item questionnaire designed to evaluate an individual's self-perception of disability associated with symptomsof dizziness. The scale consists of a 7-item physical subscale, a 9-item emotional subscale, and a 9-item functional subscale. Scores for each item range from 0 (no) to 4 (yes) with a total composite score ranged between 0 (no disability) to 100 (significant disability).A total score of 0–30 indicates mild, 31–60 moderate, and 61–100 severe dizziness handicap (Whitney et al., 2004b). The DHI demonstrated good test-retest reliability and validity (Jacobson and Newman, 1990, Whitney et al., 1999).

b. Illness Behaviour Questionnaire (IBQ)(Pilowsky and Spence, 1994) is a 62-items self-assessment instrument which assesses an individual's ideas, behavioural and attribution to the illness symptoms. The IBQ use dichotomous

scale (yes/no response) and the score responses across seven factors: General hypochondriasis (GH-anxious: health related concern), Disease conviction (DC: belief that 'a real disorder or disease is present), Psychological vs somatic focussing (P-S:tendency to attribute illness either psychological or physical causes), Denial (D: tendency to attribute life stress to physical problems), Affective inhibition (AI: Inability to express negatives personal feeling to others), Affective disturbance (AD: anxiety, depression) and Irritability(I: anger). Examples of IBQ items are ' Are you afraid of illness?' (General hypochondriasis factor) and 'Do you think there is something seriously wrong with your body?' (Disease conviction factor).

The IBQ is primarily used to provide an indication of normality (or abnormality) of an individual's behaviour towards his/her illness. These seven IBQ factors can be used to measure individual differences in illness behaviour with high score on all factors except Psychological vs Somatic perception suggesting an abnormal perception, evaluation or action in relation to a person' own health status, inhibition and irritability in relation to others (Pilowsky and Spence, 1994). Two second-order factors i.e. Affective state (AS) and Disease Affirmation (DA) are derived from the IBQ. The score for AS is obtained by the sum of scores of general hypochondriasis, affective disturbance and irritability factor, i.e. AS = GH+AD+I. While DA is a composite measure comprising the Disease conviction plus Psychological vs somatic preoccupation (P/S) scored in favour of somatic concern, i.e. DA = DC +(5-P/S). The second-order factors of IBQ provide information about global aspects of illness behaviour. Healthy controls were instructed to complete IBQ Form B format, which does not assume the individual has an illness.

4.2.3 Functional Gait Assessment (FGA)

The FGA has been described previously in Chapter 2 (section 2.2.3.2).

4.2.4 Computerized Dynamic Posturography (CDP):Sensory Organization Test

The Sensory Organization Test (SOT) was performed according to a published protocol (Equitest; Neurocom International, Oregon). Testing is performed under six different sensory conditions to assess the influence of visual, vestibular and somatosensory inputs on standing balance. In conditions 1 to 3 subjects stand on a stationary support surface with eyes open, eyes closed, and with sway-referenced vision, respectively. In conditions 4 to 6 a similar procedure is followed except the support surface is also sway referenced. The program yields an average composite equilibrium score, ranging from 0 % (no balance) to 100% (maximum stability). Scores below 70% are considered abnormal (Neurocom, 1999).

4.2.5 Data analysis

IBM SPSS statistics 19 was used for statistical analysis. Data are presented as mean ± S.D. Between-groups differences were determined using the Mann-Whitney Test. Spearman's bivariate correlation was used to assess whether there was a relationship between illness behaviour and both objective and subjective standard clinical outcome measures. Multiple regression analysis was performed to assess whether migraine, age and symptom duration would

be significant predictors to the outcome measures. Age and symptoms duration were not significantly different between-groups. Only significant findings are reported. Significant results for all tests were assumed if $p<0.05$.

4.3 RESULTS

4.3.1 Comparison of Illness Behaviour Questionnaire (IBQ) between patients and control groups

Significant between-group differences were noted for affective state (AS) ($z=-4.35$;$p=0.00$) and Disease Affirmation (DA) ($z=-6.36$;$p=0.00$) whereby scores were higher (i.e. worse) for Group P. A significant effect of migraine on both affective state ($F_{(1,99)}=17.1$, $p<0.05$] and disease affirmation ($F_{(1,99)}=49.9$, $p<0.05$] was identified with higher (i.e. worse) scores in those with migraine after controlling for age and symptom duration. Mean (SD)of the second order factors(i.e. AS and DA) in patients for with vestibular disorders with and without migraine components are displayed in Figure 18.

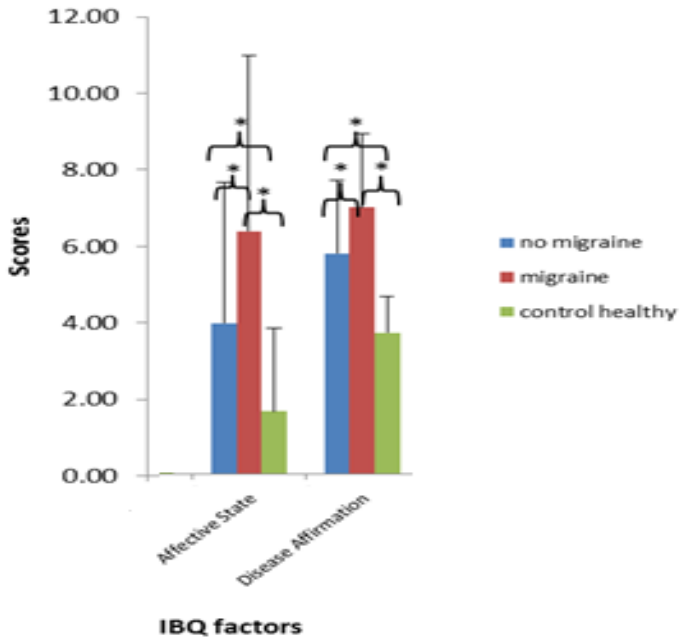


Figure 18 Mean (SD) of the Affective state and Disease affirmation (IBQ second order-factors) between studied groups.

Abbreviation: IBQ= Illness behaviour questionnaire. *p<0.05 indicates significant different between groups.

Analysis on the IBQ domains showed a significant effect of group on General hypochondriasis [$F_{(2,101)}$= 6.0, p<0.05], Disease conviction [$F_{(2,101)}$= 34.9, p<0.05], Affective disturbance [$F_{(2,101)}$= 14.5, p<0.05] and Irritability [$F_{(2,101)}$= 10,4, p<0.05]. Following post-hoc analysis, both disease conviction (DC) and affective disturbance (AD) scores significantly different between the groups wherein migraniuers scores significanlty higher (i.e. worse) compared to non-migraineurs and healthy control groups [DC $t_{(101)}$=4.9; p<0.05; AD $t_{(101)}$=2.6,p<0.05]. Figure 19 shows mean (+SD) of the IBQ in patients with vestibular disorders with and without migraine components.

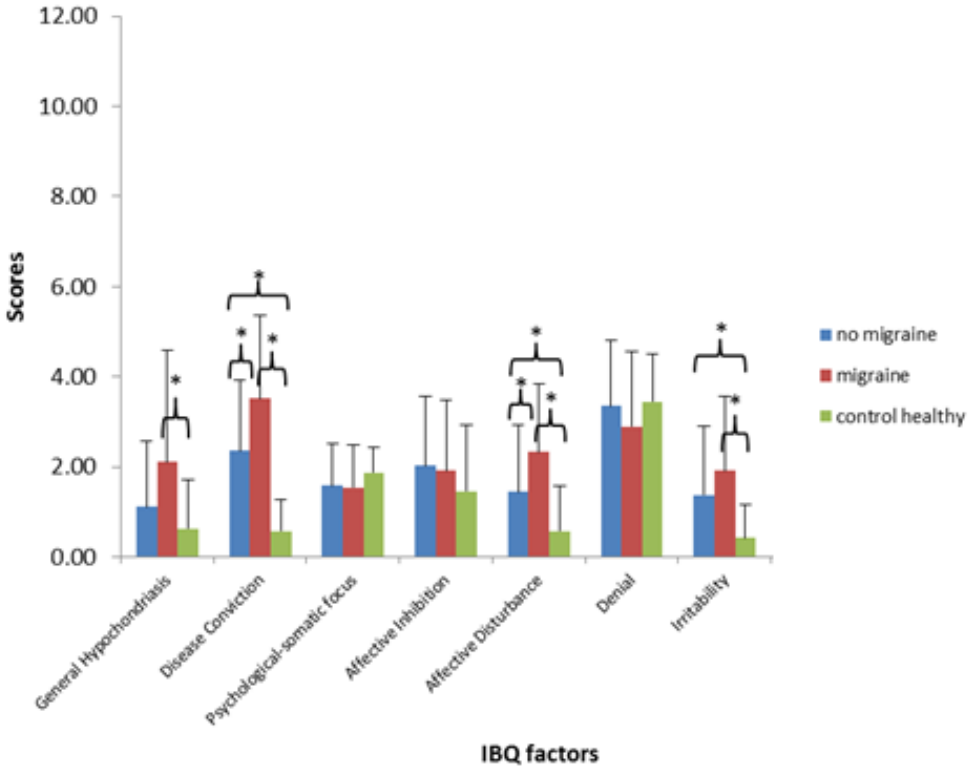


Figure 19 Mean (SD) of the IBQ subscales score between healthy control, patients with and without migraine.

Abbreviation: IBQ= Illness behaviour questionniare

4.3.2 Association between IBQ Second-order factors and outcome measures in patients.

Increased affective state or disease affirmation scores were significantly associated with greater anxiety ($p<0.05$), depression ($p<0.05$)autonomic anxiety ($p>0.05$), visual vertigo ($p<0.05$) and DHI subscale scores ($p<0.05$) as well as with decreased balance confidence ($p<0.05$) and each VDADL subscales ($p<0.05$) scores. Computerised dynamic posturography (CDP) was significantly associated with affective state ($r=0.25;p=0.04$) in which increased (i.e. worse) affective state was associated with increased (i.e. better) CDP performance. Correlation coefficient values were presented in table 11 and only data with significant findings were displayed.

Table 11 Correlation coefficient values of IBQ and self-reported outcome measures

	SVQ	HAD-A	HAD-D	ABC	VSS-A	DHI-E	DHI-F	DHI-P	VADL-F	VADL-A	VADL-I
Affective state	r_s=0.28 p=0.02	r_s=0.63 p=0.00	r_s=0.52 p=0.00	r_s=-0.28 p=0.02	r_s=0.42 p=0.00	r_s=0.43 p=0.00	r_s=0.28 p=0.02	n.s.	n.s.	n.s.	n.s.
Disease affirmation	r_s=0.33 p=0.01	r_s=0.48 p=0.00	r_s=0.56 p=0.00	r_s= -0.41 p=0.00	r_s=0.33 p=0.01	r_s=0.48 p=0.00	r_s=0.46 p=0.00	r_s=0.31 p=0.01	r_s=0.32 p=0.01	r_s=0.34 p=0.00	r_s=0.33 p=0.01

Abbreviations: SVQ=Situational Vertigo Questionnaire;HAD-A=Hospital Anxiety and Depression (Anxiety scale);HAD-D=Hospital Anxiety and Depression (Depression scale); VSS-A=Vertigo Symptom Scale (autonomic and somatic anxiety symptoms);ABC=The Activities Specific Balance Confidence Scale; VADL-F= Vestibular Activities of Daily Living Scale (functional subscale); VADL-A= Vestibular Activities of Daily Living Scale (ambulation subscale); VADL-I= Vestibular Activities of Daily Living Scale (Instrument subscale); DHI-T= Dizziness Handicap Inventory (total score); DHI-P=Dizziness Handicap Inventory (Physical subscale); DHI-E= Dizziness Handicap Inventory (Emotional subscale); DHI-F=Dizziness Handicap Inventory (Functional subscale). Significant level $p<0.05$; n.s= not significant.

4.3.3 Self-reported outcome measures

Significant differences were noted between-groups for all self-reported outcome measures i.e. SVQ, VSS, ABC, VADL, HAD and DHI scales. Group P scored significantly lower (i.e worse) on the ABC scale [z=-6.97; p<0.01] and showed a significantly higher (i.e worse) mean score for all other scales [VADL subscale,F:z=-6.50; p<0.01; A:z=-6.77;p<0.01; and I:z=-6.62; p<0.01; VSS-V:z=-7.28;p<0.01 and VSS-A:z=-6.57;p<0.01; HAD-A:z=-5.69;p<0.01 and HAD-D:z=-5.57;p<0.01; SVQ:z=-6.49;p<0.01; DHI-E:z=7.67;p<0.01; DHI-F:z=-7.64;p<0.01 and DHI-P:z=-7.77;p<0.01] compared to Group C. Descriptive data and statistics are displayed in Table 12.

Table 12 Mean (SD) score and range for self-reported outcome measures between healthy controls and people with a vestibular disorder, with and without migraine.

Groups/ Variables Mean(SD) [Range]	**Group C**	**Group P (Total)**	**Group P**	
			Without migraine	**Migraine**
SVQ	0.22 (0.29) [0-1.05]	1.50 (0.97)* [0-4]	1.22 (0.91) [0-3.56]	1.75 (0.91) * [0-4]
HAD-A	3.21 (2.69) [0-11]	8.69 (4.45)* [0-19]	7.06 (3.46) [1-13]	10.19 (4.77) * [0-19]
HAD-D	1.61 (2.21) [0-7]	6.04 (4.28)* [0-20]	4.76 (3.88) [0-14]	7.22 (4.35) * [1-20]
ABC	96.15 (4.42) [80-100]	66.62 (23.95)* [0-99]	72.62 (21.44) [26-99]	61.25 (25.01) * [0-98]

VADL-F	1.02 (0.06) [1-1]	2.24 (1.18)* [1-5]	2.23 (1.14) [1-5]	2.24 (1.22) [1-5]
VALD-A	1.02 (0.08) [1-1]	2.66 (1.39)* [1-7]	2.45 (1.27) [1-5]	2.85 (1.48) [1-7]
VADL-I	1.01 (0.05) [1-1]	2.95 (1.97)* [1-10]	2.79 (1.97) [1-8]	3.09(1.99) [1-10]
VSS-A	0.21 (0.24) [0-1]	1.09 (0.75)* [0-3.43]	0.76 (0.54) [0-2.07]	1.41(0.79) * [0.40-3.43]
VSS-V	0.07 (0.10) [0-0.47]	0.89 (0.71)* [0-3.42]	0.81 (0.79) [0-3.42]	0.97 (0.62) [0-2.37]
DHI-E	0.18 (0.77) [0-4]	13.03 (8.60)* [0-34]	10.18 (8.46) [0-30]	15.58 (8.00) * [0-34]
DHI-F	0.12 (0.70) [0-4]	16.19 (9.75)* [0-34]	13.94 (10.43) [0-32]	18.21 (8.74) [0-34]
DHI-P	0.30 (1.74) 90-10]	13.17 (6.88)* [0-28]	12.18 (6.61) [0-24]	14.05 (7.08) [0-28]

Abbreviations: Group P= all patients; Group C= control healthy; SVQ=Situational Vertigo Questionnaire;HAD-A=Hospital Anxiety and Depression (Anxiety scale);HAD-D=Hospital Anxiety and Depression (Depression scale); VSS-V=Vertigo Symptom Scale (common vestibular symptoms); VSS-A=Vertigo Symptom Scale (autonomic and somatic anxiety symptoms);ABC=The Activities Specific Balance Confidence Scale; VADL-F= Vestibular Activities of Daily Living Scale (functional subscale); VADL-A= Vestibular Activities of Daily Living Scale (ambulation subscale); VADL-I= Vestibular Activities of Daily Living Scale (Instrument subscale); DHI-T= Dizziness Handicap Inventory (total score); DHI-P=Dizziness Handicap Inventory (Physical subscale); DHI-E= Dizziness Handicap Inventory (Emotional subscale); DHI-F=Dizziness Handicap Inventory (Functional subscale).

The asterisks (*) denotes a significant between-group differences, $p<0.05$.

Multiple regression was conducted to predict the effect of migraine, the symptom duration and age of patient participants on each subjective outcome measures. The prediction model was statistically significant for ABC (R^2=0.12, F(3,67)=91.7,p<0.05), Depression subscale of HAD (R^2=0.10, F(3,67)=4.13, p<0.05), Emotional subscale of DHI (R^2=0.12, F(3,67)=10.7,p<0.05) and VSS-A (R^2=0.23, F(3,67)=1.03, p<0.05) and migraine was demonstrated to be a significant predictor to poor subjective outcome measures.

4.3.4 Objective measures

Both FGA and CDP composite scores were significantly lower (i.e. worse) in Group P compared to Group C [FGA:z=-5.50;p=0.00; CDP:z=-4.19;p=0.00]. Following the multiple regression analysis, age is the only significant predictor of FGA scores in patients [R^2=0.15, adjusted R^2=0.11, F(3,66)=3.95, p<0.05].Descriptive data and statistics are displayed in Table 13.

Table 13 Mean (SD) of objective outcome measures

Variable	Group C	Group P
FGA	28.48 (1.70)	24.08 (4.99)**
CDP	75.15 (9.33)	60.22 (18.01)**

Abbreviations:FGA= Functional Gait Assessment; CDP=Computerised Dynamic Posturography.The asterisks (*) denotes a significant between-group differences (**p<0.01)

4.4 DISCUSSION

The aims of this study were to investigate illness behaviour patterns in patients with vestibular disorder and/or vestibular migraine as compared to healthy controls, to look at the effect of migraine on outcome measures and to assess the association between illness behaviour, functional gait, postural control and subjective symptoms in patients. Overall, Affective state (AS) and Disease affirmation (DA) of IBQ second order factor scores differed significantly between groups with higher (i.e. worse) score noted in patients with migraine. Patients with migraine also scored worse on Disease conviction and Affective disturbance of IBQ domain. These findings suggest that the IBQ can be used to differentiate illness behaviour patterns between patients with vestibular disorders (including migraine) and healthy controls. Increased Affective state or Disease affirmation scores were significantly associated with greater anxiety, depression, visual vertigo, and self-perception of disability as well as with reduced balance confidence and activity of daily living. The discussion is separated into (i) illness behaviour profile in patients with vestibular disorders and/or migraine, (ii) relationship between illness behaviour and standard clinical outcome measures and (iii) clinical implications.

(i) Illness behaviour profile in patients with vestibular disorders with and without a migraine component

Current findings revealed that IBQ profile was significantly different between person with a vestibular disorder and healthy individuals and also between person with and without migraine history. Scores on Disease Conviction, Affective disturbance domains as well as the second-order factors of IBQ (i.e. Affective state (AS) have been shown capable to differentiate between the experimental groups with higher (i.e. worse) scores in those with migraine. High scores on both second order factors suggest global aspects of abnormal illness behaviour (Pilowsky & Spence, 1994).

The IBQ does not have a predefined threshold for each of its subscales that categorise a given score as abnormal. Some cut-off scores have been provided in the IBQ manual (Pilowsky and Spence, 1994) which were set from a particular setting (i.e. pain clinic and general practice). Apart from the cut-offs, the scale scores can be used in their raw forms and can be considered in relation to a normative population. Pilowsky and Spence (1994) suggested that the mean score of ≥ 3 on disease conviction can be used to identify abnormal illness behaviour in patients with a chronic low back pain. Similar finding was also noted in a stroke rehabilitation population with a subtle modification on the cut-off point for disease conviction (Clark and Smith, 1997). The authors suggested that mean score of ≥2 on disease conviction is able to differentiate between patients who developed abnormal illness behaviour and those who were not in stroke rehabilitation setting (Clark and Smith, 1997). Data from the current study showed patients with migraine has a mean score of >3 on the disease conviction dimension which suggests abnormal illness behaviour.

However the interpretation of the current finding based on the suggested cut-off point should be conducted with caution due to different patients population.

Pilowsky and Spence (1994) indicated that a high score on Affective disturbance domain suggests that a high level of anxiety and/or depression may be present. It was noted in the current study that patients with migraine scored higher on the Affective disturbance domain than those without migraine. In addition, higher (i.e. worse) anxiety and depression mean scores were also noted in individuals with migraine. It is known that anxiety-related disorders or depression are strongly associated with vestibular disorders and vertigo (Godemann et al. 2005). There was evidence showing vestibular migraine, anxiety and depression are linked with somatoform vertigo and dizziness (SVD) and some patients with vestibular disorders were susceptible to develop SVD (Tscahn et al., 2011) or abnormal illness behaviour (Savastano et al., 1996). A study on patients with Meniere's Disease (MD) demonstrated that anxious or depressed MD patients had a tendency to interpret their illness in somatic term compared to those emotionally stable patients (without anxiety or depression) (Savastano et al., 1996). Although not all patients with a vestibular disorder or migraine develop a psychiatric disorder, it is useful to screen those who are at risk of developing SVD. Therefore this suggests the potential use of IBQ as a tool to identify patients with greater risk of developing somatoform or chronic subjective dizziness. However more study using the IBQ is needed to understand the association between psychological state, abnormal illness behaviour and chronic subjective dizziness.

The current study also revealed that person with migraine scored higher on both second-order factors (Affective state and Disease affirmation) as compared to

non migrainuers and healthy groups. Affective state (AS) measures the global degree of depression, anxiety, irritability and phobic concern about one's healthy while disease affirmation evaluates the tendency to perceive the somatic symptoms of the disease, explaining them in term of physical illness. This is not unexpected as second-order factors are a combination of individual IBQ dimensions (Pilowsky and Spence, 1994). Previously, Disease affirmation and Affective state scores have been shown able to predict abnormal illness behaviour in different patient populations including chronic pain (Pilowsky and Spence, 1994) and stroke (Clark and Smith, 1997). Pilowsky and Spence (1994) suggested that the mean score of ≥ 7 on Disease affirmation can be used to identify abnormal illness behaviour in patients with a chronic low back pain. More works need to be done using the IBQ to determine the levels of abnormal illness behaviour in the current study patient cohort.

Overall, the IBQ profile from the current study revealed that person with a migraine show a significantly greater fear concern about their health status, disease conviction, dysphoria and irritability. More importantly a tendency for somatisation was noted in migraine. The IBQ profile for migraine was comparable to those reported in person with chronic pain (Piloswky and Spence, 1994). Link between balance, migraine and anxiety disorders as well as pain has been discussed extensively (Balaban, 2011, Balaban et al., 2011). High levels of psychiatric disturbance and pain (in the case of vestibular migraine) are key features of vestibular disorders. Shared organizational and neurochemical features of the vestibular system and pain information explain some aspects of the co-morbid balance disorder and interactions between anxiety and migraine (Balaban et al. 2011). The role of psychological factors in the manifestation of chronic pain is well documented and 'Attention

management' (e.g. Cognitive-behavioural therapy) a treatment approach that helps in shifting patient's attention from focussing on structural pathology as the cause of pain (somatic focus) to pyschosocial focus has been noted beneficial for a chronic pain treatment (Morley, 2011). Previous study highlighted on the neural pathways link between balance, anxiety, pain and migraine. Current study findings showed similarity in IBQ scores between migraine and chronic pain disorders. These findings suggest work on chronic pain management might be relevant to patients with vestibular disorder particularly with migraine component.

There is a vast literature concerning abnormal illness behaviour or inappropriate responses to illness as measured by the IBQ, traditionally in patients with chronic pain (Pilowsky and Katsikitis, 1994, Waddell et al., 1989, Large and Mullins, 1981, Main and Spanswick, 1995, Margoles, 1990) and psychiatric problem (Pilowsky, 1993b, Boyle and Le Déan, 2000, Guo et al., 2001, Duddu et al., 2006, Lykouras et al., 2006). However such studies often represent isolated application of the IBQ to a particular illness.The IBQ has been used successfully to understand illness behaviour patterns in patients with a Meniere's Disease (Savastano et al., 1996). Findings of the current study demonstrated that person with migraine has a tendency for somatisation and similar tendency was also reported previously in patients with MD (Savastano et al., 1996). High level of psychological disturbance (i.e. anxiety or depression) and pain in addition to unpredictable, more severe and uncontrollable nature of attacks in both vestibular migraine and Meniere's disease could possibly explain the abnormal illness behaviour observed. This suggests that the IBQ is suitable to be used in patients with vestibular disorders including migraine.

Illness behaviour plays an important role in the development of unexplained physical symptoms and is one of most frequent reasons for which people seek medical help (Rief et al., 2001). Irrespective of the actual mechanism involved in the formation of the symptoms, assessing inappropriate illness behaviour may offer insight into the reasons why some individuals display symptoms or signs which are not consistent with medical diagnosis or less responsive to treatment. Further exploration of the IBQ in patients with vestibular disorder or migraineurs should also promote a clearer understanding of the nature of abnormal illness behaviour observed in this group of patients.

(ii) Relationship between illness behaviour and standard clinical outcome measures in patients

Current findings show that both second-order factors i.e. affective state and disease affirmation correlated significantly with all self-reported outcome measures except VSS-V. This is suggesting increased autonomic/somatic anxiety, increased disability, reduced ability of ADL, poor balance confidence are associated with worse affective state and increased disease affirmation. Furthermore migraine has been shown as the highest predictor on both affective state and disease affirmation.

The IBQ has been shown to be associated with psychological state i.e. anxiety or depression in various patient populations (Fava et al., 1982, Rief et al., 2005, Guo et al., 2001, Lykouras et al., 2006), physical quality of life (i.e. ALD & social activities) (Clark & Smith, 1997; 1998) and chronic pain (Pilowsky and Spence, 1994, Keefe et al., 1986). It is well documented that poor psychological state associated with abnormal illness behaviour (AIB) could exacerbate the

impact of illness behaviour (Fava et al., 1982, Hobbis et al., 2003, Clark and Smith, 1997).

No study to date have investigated the effect of abnormal IBQ and treatment outcome. A study in person with stroke reported that AIB has been associated with reduced performance in activities of daily living (ADL)(Clark and Smith, 1998) measured at the time of discharged and at 12 months after rehabilitation. Reduced social activities level was also noted in patients with AIB in respect to the non-AIB (Clark and Smith, 1998). In addition, the authors also investigated the effect of depression and AIB in a long-term rehabilitation outcomes for stroke patients. The finding showed that ADL ability measured at 12 months following discharge from stroke rehabilitation was predominantly a function of AIB and depression was not. The authors concluded that AIB is a key determinant of long term functional disability while depression associated with poorer social functioning in patients with stroke (Clark and Smith, 1998). These studies support finding of the current study which showed significant association between increased IBQ second-order factor scores and reduced ADL ability in patients with vestibular disorders or migraine. However further research is needed to identify the relationship between IBQ and treatment outcomes.

Affective state (AS) was positively correlated with computerised dynamic posturography (CDP) in which increased AS was associated with better CDP performance. The computerised dynamic posturography (CDP) is an objective assessment tools that allow quantification of postural sway during stance under dynamic conditions (changing surface and/or visual conditions). The Sensory Organisation Test (SOT), one of the specific CDP test, provides systematic evaluation of the main sensory systems involved in balance control. Several

studies have demonstrated the association between impaired (i.e. low) SOT equilibrium scores and fall risks in patients with vestibular disorder (Whitney et al. 2006) and older adults (Girardi et al., 2001). However association between posturography and psychological state has not clearly explored. One study found no association between posturography and subjective outcome measures (questionnaire) relating to vertigo symptoms experienced during the previous month, visual vertigo, and emotional state in patients with peripheral vestibular disorders (Pavlou et. al., 2004). In our study, it was unclear as to why positive association between affective state and posturography has been shown here in patients with peripheral vestibular disorders and migraine. Further studies are needed to clarify what this means in term of objective balance tests, particularly in light of the concerns about the effectiveness of posturography in detecting abnormalities in the studied patients' population.

iii) Clinical implications

The study of illness behaviour has many applications in research, clinical care, public health, and social policy (Mechanic, 1986). At a clinical level, awareness on how people interpret illness, present symptoms, and respond to medical care can improve understanding thereby helping health professionals to provide more effective management.

Illness behaviour places primary emphasis on illness responses at the level of the individual (Mechanic, 1986). It affects how person attends to somatic information, interprets and respond to symptoms, and finally seeks medical care. Although symptoms may objectively share quite similar characteristics,

there is substantial inter-individual variability in the manner in which people perceive, interpret, and therefore respond to symptoms (Sirri and Grandi, 2012).

The role of psychological factors in the manifestation of illness behaviour is well noted. It is importance to highlight the existence of psychiatric co-morbidity in patients with a vestibular disorder including those with migraine component. It is known that vestibular rehabilitation is the mainstay of treatment for patients with vestibular disorders, in combination with anti-migraine prophylaxis for patients with vestibular migraine (Wrisley et al., 2002, Alghadir et al., 2013, Herdman et al., 2012). Although the majority of patients improve, some do not (Herdman et al., 2012). Further work needs to be done to investigate the relationship between illness behaviour and treatment outcome. Recent work has shown that cognitive-behavioural therapy (CBT) may be a beneficial adjunct to treatment in patients with a vestibular disorder although future work is needed (Schmid et al., 2011, Edelman et al., 2012). Greater reduction in anxiety, depression and self-reported handicap was reported among patients with dizziness following 8 to12 weeks of both self-administered VR and CBT compared to those who only received in isolation (Holmberg et al., 2006). A more recent study showed that dizziness-related symptoms, disability and functional impairment significantly improve following shorter CBT intervention (3 sessions) (Edelman et al., 2012). It is important to acknowledge the effectiveness of CBT and physical therapy to reduce anxiety, depression and disability related to chronic dizziness. It is also important to highlight the link between abnormal illness behaviour and depression (Clark and Smith, 1997).The authors suggested that the most likely cause to the AIB emergence was factors intrinsic (i.e. depression) to the patients, although factors such as medical condition and rehabilitation environment should not be neglected (Clark and Smith, 1997). Therefore this

gives credence to the possibility that treating psychological problem (i.e. depression) may hinder development of abnormal illness behaviour. However further works are needed to explore the impact of rehabilitation and medical management on illness behaviour as well as to investigate the long-term outcomes in patients with vestibular disorder including vestibular migraine.

Understanding how patients behave towards their illness may lead to a better treatment strategies for patients with a vestibular disorder in future. It is important to acknowledge combined treatment for holistic multidisciplinary. Early diagnosis and appropriate referral could result in effective and efficient management of illness behaviour in patients with a vestibular disorder including migraine.

Preliminary findings of the current study have provided valuable information regarding the illness behaviour profile in patients with a vestibular disorder and vestibular migraine. Previous study highlighted the link between vestibular disorders and anxiety or depression (Godemann et al., 2005) as well the link between anxiety and depression with chronic somatoform vertigo and dizziness (SVD) (Tschan et al., 2011; Staab and Ruckenstien, 2003). However analysis on this aspect could not be done due to lack of data related to SVD in the current study. Therefore it is suggested to extend investigations to include other group of patients who experience chronic dizziness in the absence of an active physical neuro-otological deficit (i.e. psychogenic). Hopefully it will help to elucidate the link between abnormal illness behaviour and the underlying cause of dizziness.

Conclusion

Findings indicate that patients with a vestibular disorder including migraine have an IBQ profile that differs from that in an age-matched healthy control group. Patients with a vestibular migraine show a significantly greater fear concern about their health status, disease conviction, dysphoria and irritability. Importantly a tendency for somatisation was noted in these patients which has implications for future management strategies. Future studies should investigate the relationship between specific vestibular diagnoses and illness behaviour, the effect of illness behaviour on treatment outcome and the role of CBT methods in the treatment of illness behaviour in patients with a vestibular disorder.

CHAPTER 5: GENERAL DISCUSSION AND CONCLUSION

The results of each experimental study were presented and discussed in the relevant chapters. This discussion chapter will provide a summary of all results and a general overview of the entire research.

Thesis summary

Balance control during bipedal gait is an interaction of many systems and subsystems within an individual and its surrounding environment. It is known that functional maintenance of balance requires integration of multiple sensory inputs from the visual, somatosensory and vestibular systems as well as appropriate muscle strength, movement strategies and cognitive function. Impaired performance in any of these functions may lead to postural instability and increase risk of falls (Harris et al., 2005, Herdman et al., 2000). In addition, the ability to adapt gait according to environmental and task demands is crucial when navigating in challenging and unpredictable environments such as during community ambulation (Patla, 2001).

Eight environmental dimensions have been identified as important factors for safe and independent mobility within the community (Patla and Shumway-Cook 1999). The eight environmental dimensions include distance, speed, ambient conditions (e.g. light level, weather conditions), terrain characteristics, physical load, attentional demands, postural transition and traffic level. It has been proposed that these dimensions are critical determinants of mobility disability because disability is inversely related to the ability to effectively manage the demands within each environmental dimension (Shumway-Cook et al., 2003). Most studies focusing on postural control during ambulation have been

conducted either in a laboratory or clinical setting, which may not reflect the complex environmental and task demands encountered during community ambulation (Chastan et al., 2010, Bhatt and Pai, 2009, Iosa et al., 2012b).

The ultimate goal of gait analysis is to identify the underlying causes of balance impairments. Instrumented three-dimensional (3D) gait analysis system provides quantitative measures and has been accepted as a 'gold standard' assessment for gait in patient populations including stroke (Ferrarello et al., 2013). Despite advantages offered by the standard instrumented 3D gait analysis system (e.g. camera-based system), the use of the system in a clinical setting is still restricted by the fact that the system is complex, time demanding, expensive and requires a high-level interpretive skills (Coutts, 1999). Thus, observational gait analysis (i.e. naked-eyes or video-taped) remains as a preferred gait assessment method in clinical settings (Ferrarello et al., 2013) despite its high degree of subjectivity in the interpretation of gait impairment compared to instrumented gait analysis system (Ferrarello et al., 2013).

Accelerometers are wearable motion sensors that have been shown to be reliable and are cost-effective alternative for the measurement of gait (Mayagoitia et al., 2002, Kavanagh et al., 2006). They provide an objective measurement of postural control during gait and can quantify gait pattern in healthy individuals and individuals with balance or gait problems e.g. elderly, stroke, Parkinson disease, multiple sclerosis (Menz et al., 2003c, Menz et al., 2003a, Huisinga et al., 2012, Latt et al., 2009, Iosa et al., 2012b). Accelerometer allows continuous data collection over an extended time and over long distances which are the main limitation in a standard instrumented gait analysis system. Furthermore accelerometers are relatively easy to

manage operating system, portable and lightweight thus allowing gait data collection in the environment (i.e. indoor or outdoor setting) which is not feasible for camera-based system. Based on the literature, we know that people with a vestibular disorder or stroke experience difficulties ambulating in real environment (Iosa et al., 2012a, Donovan et al., 2008,Lord et al., 2006) and accelerometers are available now to allow us to measure this.

The first two studies (Chapter 2 and Chapter 3) of the current thesis explored the effectiveness of use of accelerometers in measuring upper body stability control when walking in real urban environment for healthy individuals and individuals with a vestibular disorder or stroke. The findings of the current study showed that accelerometers can be used to measure gait and balance impairment particularly in outdoor settings i.e. urban walking environment. The findings demonstrated that accelerometers were able to differentiate the postural strategies utilised by people with a vestibular disorder or stroke compared to healthy controls. More specifically, both patient groups employed compensatory mechanisms including reduced walking speed and reduced trunk accelerations in order to maintain postural stability during gait in urban environments. However, greater AP head accelerations were noted in patients with stroke, indicating that stroke patients have difficulties stabilizing their head in space during walk in urban environment. In addition, mobilising on uneven surfaces had greatest effect and induced head instability particularly in ML direction in patients with vestibular disorders and in the AP direction (the direction of progression) in patients with stroke. These results indicate that walking in an urban environment provides challenges to postural stability control in people with vestibular disorders or stroke. It has been reported that reduced gait speed is a compensatory strategy to reduce upper-body accelerations and

maintain balance in patients with sub-acute stroke (Iosa et al., 2012a; Iosa et al., 2012b) and in older adults (Menz. et al., 2003c). Impairment of neuromuscular and musculoskeletal systems following stroke however could further compromise postural control, particularly at the head level in the direction of progression wherein greater head acceleration may interfere with the maintenance of gaze stability during ambulation.

In this thesis, significant correlation has been noted between accelerometry data and some standard clinical assessment tools i.e. Time up and go (TUG) and Functional gait assessment (FGA). Functional gait assessment or time up and go is a commonly used clinical tool for assessing functional mobility in patient populations including those with vestibular disorders (Wrisley et al., 2004, Whitney et al., 2004a, Gil-Body et al., 2000) or stroke (Ng and Hui-Chan, 2005). Both FGA and TUG are useful screening tools to identify potential balance problems and predict falls risk however they do not provide information regarding quality of performance such as ability to modify gait to task demands. Findings of the current studies suggested that data from accelerometry could be used to assess dynamic functional performance which may be helpful in understanding the underlying cause of balance and gait impairments that may limit functional independence in patients with a vestibular disorder or stroke.

The final study (Chapter 4) of the thesis investigated the pattern of illness behaviour by using illness behaviour questionnaire (IBQ) in patients with vestibular impairment including vestibular migraine. Findings of this study showed that the IBQ can be used to differentiate illness behaviour patterns between patients with vestibular disorders including vestibular migraine and healthy controls. Patients with vestibular migraine show a significantly greater

fear concern about their health status, disease conviction, dysphoria and irritability which suggested the global aspects of abnormal illness behaviour. In addition greater anxiety and depression level were also noted in people with migraine.

The term *abnormal illness behaviour* (AIB) is used to describe individuals with maladapted response to an underlying organic pathology or diagnosis and when inappropriate treatment is sought (Mechanic, 1986). Although symptoms may share similar clinical characteristics, different forms of illness behaviour may be elicited suggesting substantial inter-individual variability in a way a person respond to their symptoms (Mechanic, 1986). Our study on illness behaviour provides a possible profile of AIB in people with vestibular disorders, particularly those with migraine components, namely high level anxiety and depression and showed a tendency for somatisation. Early detection of possible somatisation in patients with migraine may lead to better intervention. Early intervention will allow abnormal illness beliefs and attitudes to be modified before it becomes resistant to change.

It is known that illness behaviour questionnaire (IBQ) has been used to assess abnormal illness behaviour (AIB) in various patient populations but traditionally it was used more in patients with chronic pain or with a psychiatric condition (Prior and Bond, 2008). The IBQ has also been used successfully in patients with Meniere's Disease (Savastano et al., 1996) and the current study has given further support to the fact that IBQ is well-placed to be used in wider subgroups of patient with vestibular disorders. Having said that, the association between somatisation, psychological factors and illness behaviour in patients with vestibular disorder or vestibular migraine require further exploration. Further

exploration of the IBQ could promote a clearer understanding of the nature of AIB observed in this group of patients.

Clinical implications and future directions

The findings of Chapter 2 and 3 have highlighted the impact of vestibular disorders and chronic stroke on gait including changes in postural stability and spatio-temporal gait parameters. Most clinically available gait assessment tools and tests involve the measurement of spatial-temporal parameters such as gait speed, but do not provide information about the postural control strategies used during gait. Furthermore, the tests are commonly performed in a controlled environment and measure parameters only over a short walking distance, which may not reflect the actual conditions where balance control is challenged during community ambulation. Community ambulation usually requires patients to walk for a longer distance, around obstacles, over uneven ground and moving between indoor and outdoor settings (e.g. shopping mall, shops, local high street). Results from the first two studies (Chapter 2 & 3) successfully demonstrated the ability of accelerometers to determine actual performance in a real-environment. The acceleration patterns can be used to further explain the outcome meaning of standard clinical assessment. The standard clinical tests identify who will have greater problems with community ambulation while the accelerometers provide specific information related to balance control. Therefore using accelerometers as part of the clinical assessment may provide specific information which in turn may influence treatment strategies.

There is evidence on the influence of gait analysis data on clinical decision-making in the management of post-stroke patients (Ferrarin et al.m 2015). The use of gait analysis data has been proven to be associated with better clinical

recommendation with regards to chronic stroke care among clinicians (Ferrarin et al., 2015). This finding might support the potential use of accelerometry data which is more convenient to be used i.e. less complicated instruments compared to a standard non-wearable 3D gait analysis system, in clinical settings.

The application of accelerometers in clinical practice may be useful for various patient groups in the different departments in hospital settings. For example, in the Neurology Department, where the functional ability of patients is affected by diseases e.g. stroke or in Falls Clinic setting where patients are screened for fall risk based on mobility assessment. Although accelerometers have been shown to be a potentially useful tool to identify gait abnormality in patients with balance or vestibular disorders, a thorough evaluation and validation of its performance in different population and clinical settings is necessary. In addition, a reference data base of healthy individuals with varying subject characteristics (e.g. age) is required to ensure the correct interpretation of gait analysis and to enable identification of subtle changes in gait patterns.

The use of illness behaviour questionnaire (IBQ) has been shown to provide valuable information on how patients react to their illness symptoms. The potential use of IBQ in assessing abnormal illness behaviour patterns in different subgroups of vestibular disorders has been noted previously and in the present thesis. The role of psychological factors in the manifestation of illness behaviour is well reported. It is important to highlight the existence of psychiatric comorbidity in patients with vestibular disorders including those with migraine. Identification of psychiatric disturbance or abnormal illness behaviour could also lead to referral to an appropriate professional to deal with the psychological

factors prior to the mainstay of intervention (i.e. vestibular rehabilitation or anti-migraine prophylaxis) for patients with vestibular impairment or vestibular migraine.

Previous studies have demonstrated that abnormal illness behaviour is linked to increased utilisation of healthcare services such as the overuse of medical services or seeking unnecessary treatment (Clark and Smith, 1998, Guo et al., 2002). The presence of co morbid anxiety or depression has been shown to impede recovery in patients and has increased long-term functional disability in patients who received stroke rehabilitation (Guo et al., 2002). These studies (Clark and Smith, 1998, Guo et al., 2002) have highlighted the impact of AIB on patient's management outcomes, therefore it is important to consider assessment of AIB in patient populations who are at a higher risk for AIB.

Although IBQ have been shown to be a potentially useful tool to identify abnormal illness behaviour patients with vestibular disorders including vestibular migraine, its application in the clinical setting requires further work. Thorough evaluation and validation of IBQ responses across and within subgroups of vestibular dysfunction is necessary. In addition, the lack of normative data will make interpretation of IBQ scale in identifying abnormal illness behaviour difficult. Furthermore, the use of IBQ in clinical settings and without comparative data from a control group, may result in a high degree of subjectivity in the interpretation of data. It is not clear from the literature how illness behaviour change overtime and what factors cause individuals to respond differently to similar stressor (e.g. disease/disorder). Future studies should investigate the relationship between specific vestibular diagnoses and

illness behaviour, utilising knowledge of abnormal illness behaviour in treatment planning and to investigate its effect on the treatment outcomes.

Overall, the three studies in the current thesis present novel findings and open up to further exciting areas of research aiming at intervention options for patients with vestibular disorders, vestibular migraine or stroke. Findings from the two walking studies (Chapter 2 and Chapter 3) provide better understanding about the effect of community ambulation on gait and postural stability control in healthy individuals and in patients with vestibular disorders or stroke. Findings from illness behaviour study highlighted on the possibility of abnormal illness behaviour prevalent in certain subgroup of vestibular disorders. Investigation of patient's functional mobility in real environment and the examination of patient's illness behaviour associated with their vestibular impairment may provide a critical way to identify and better understand factors that could hinder some individuals from responding well to their interventions.

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APPENDIX 1 Situational vertigo questionnaire (SVQ)

Identification no. :_____

Today's date :_____**(DD/MM/YEAR)**

Vertigo is the medical term used for symptoms which patients often describe as feelings of unusual disorientation, dizziness, giddiness, lightheadedness or unsteadiness. Please ring a number to indicate the degree to which each of the situations listed below causes feelings of vertigo, or makes your vertigo worse. If you have never been in one of the situations then for that item ring "N.T." for "Not Tried". The categories are:

0	1	2	3	4	N.T.
Not at all	**Very slightly**	**Somewhat**	**Quite a lot**	**Very much**	**Not tried**

Riding as a passenger in a car on straight, flat roads

0 1 2 3 4 N.T.

Riding as a passenger in a car on winding or bumpy roads

0 1 2 3 4 N.T.

Walking down a supermarket aisle

0 1 2 3 4 N.T.

Standing in a lift while it stops

0 1 2 3 4 N.T.

Standing in a lift while it moves at a steady speed

0 1 2 3 4 N.T.

Riding in a car at a steady speed

0 1 2 3 4 N.T.

Starting or stopping in a car

0 1 2 3 4 N.T.

Standing in the middle of a wide open space (e.g. large field or square)

0 1 2 3 4 N.T.

Sitting on a bus

0 1 2 3 4 N.T.

Standing on a bus

0 1 2 3 4 N.T.

Heights

0 1 2 3 4 N.T.

Watching moving scenes on the T.V. or at the cinema

0 1 2 3 4 N.T.

Travelling on escalators

0 1 2 3 4 N.T.

Looking at striped or moving surfaces (e.g. curtains, Venetian blinds, flowing water)

0 1 2 3 4 N.T.

Looking at a scrolling computer screen or microfiche

0 1 2 3 4 N.T.

Going through a tunnel looking at the lights on the side

0 1 2 3 4 N.T.

Going through a tunnel looking at the light at the end

0 1 2 3 4 N.T

Driving over the brow of a hill, around bends, or in wide open spaces

0 1 2 3 4 N.T.

Watching moving traffic or trains (e.g. trying to cross the street, or at the station)

0 1 2 3 4 N.T.

APPENDIX 2 Hospital anxiety and depression scale

Hospital Anxiety and Depression Scale (HADS)

Identification no. : _____

Today's Date : _____ (DD/MM/YEAR)

Please pick the answer that most accurately describe your current feelings.

1	**I feel tense or 'wound up':**	
	Most of the time	3
	A lot of the time	2
	From time to time, occasionally	1
	Not at all	0

2	**I still enjoy the things I used to enjoy:**	
	Definitely as much	0
	Not quite so much	1
	Only a little	2
	Hardly at all	3

3	**I get a sort of frightened feeling as if something awful is about to happen:**	
	Very definitely and quite badly	3
	Yes, but not too badly	2
	A little, but it doesn't worry me	1
	Not at all	0

4	**I can laugh and see the funny side of things:**	
	As much as I always could	0
	Not quite so much now	1
	Definitely not so much now	2
	Not at all	3

5	**Worrying thoughts go through my mind:**	
	A great deal of the time	3
	A lot of the time	2
	From time to time, but not too often	1
	Only occasionally	0

6	**I feel cheerful:**	
	Not at all	3
	Not often	2
	Sometimes	1
	Most of the time	0

7	**I can sit at ease and feel relaxed:**	
	Definitely	0
	Usually	1
	Not Often	2
	Not at all	3

8	**I feel as if I am slowed down:**	
	Nearly all the time	3
	Very often	2
	Sometimes	1
	Not at all	0

9	**I get a sort of frightened feeling like 'butterflies' in the stomach:**	
	Not at all	0
	Occasionally	1
	Quite Often	2
	Very Often	3

10	**I have lost interest in my appearance:**	
	Definitely	3
	I don't take as much care as I should	2
	I may not take quite as much care	1
	I take just as much care as ever	0

11	**I feel restless as I have to be on the move:**	
	Very much indeed	3
	Quite a lot	2
	Not very much	1
	Not at all	0

12	**I look forward with enjoyment to things:**	
	As much as I ever did	0
	Rather less than I used to	1
	Definitely less than I used to	2
	Hardly at all	3

13	**I get sudden feelings of panic:**	
	Very often indeed	3
	Quite often	2
	Not very often	1
	Not at all	0

14	**I can enjoy a good book or radio or TV program:**	
	Often	0
	Sometimes	1
	Not often	2
	Very seldom	3

APPENDIX 3 Vestibular disorders activities of daily living scale

ID:_____ Rater: _____ Date:_____(DD/MM/YEAR)

Instructions

This scale evaluates the effects of vertigo and balance disorders on independence in routine activities of daily living. Please rate your performance on each item. If your performance varies due to intermittent dizziness or balance problems please use the greatest level of disability. For each task indicate the level which most accurately describes how you perform the task. If you never do a particular task, please check the box in column NA. The rating scales are explained below.

Explanation of Independence Rating Scale

This scale will help us to determine how inner ear problems affect your ability to perform each task. Please indicate your current performance on each task, as compared to your performance beforedeveloping an inner ear problem, by checking one of the columns in the center of the page. Pick the answer that most accurately describes how you perform the task.

1	**I am not disabled, perceive no change in performance from before developing an inner ear impairment.**
2	I am uncomfortable performing the activity but perceive no difference in the quality of my performance.
3	I perceive a decrement in the quality of my performance, but have not changed the manner of my performance.
4	I have changed the manner of my performance, eg, I do things more slowly or carefully than before, or I do things without bending.
5	I prefer using an ordinary object in the environment for assistance (eg, stair railing) but I am not dependent on the object or device to do the activity.
6	I must use an ordinary object in the environment for assistance, but I have not acquired a device specifically designed for the particular activity.
7	I must use adaptive equipment designed for the particular activity (eg, grab bars, cane, reachers, bus with lift, wedge pillow).
8	I require another person for physical assistance or, for an activity involving 2 people, I need unusual physical assistance.
9	I am dependent on another person to perform the activity.
10	I no longer perform the activity due to vertigo or a balance problem.
NA	I do not usually perform this task or I prefer not to answer this question.

Independent rating	Independent	Uncomfortable, no change in activity	Decreased ability, no change in manner of performance	Slower, cautious, more careful	Prefer using an object for help	Must use an object for help	Must use special equipment	Need physical assistance	Dependent	Too difficult, no longer
Task	1	2	3	4	5	6	7	8	9	10
F-1 Sitting up from lying down										
F-2 Standing up from sitting on the bed or chair										
F-3 Dressing the upper body (eg, shirt, brassiere, undershirt)										
F-4 Dressing the lower body (eg, pants, skirt, underpants)										
F-5 Putting on socks or stockings										
F-6 Putting on shoes										
F-7 Moving in or out of the bathtub or shower										

Independent rating	Independent	Uncomfortable, no change in activity	Decreased ability, no change in manner of performance	Slower, cautious, more careful	Prefer using an object for help	Must use an object for help	Must use special equipment	Need physical assistance	Dependent	Too difficult, no longer
Task	1	2	3	4	5	6	7	8	9	10
F-8 Bathing yourself in the bathtub or shower										
F-9 Reaching overhead (eg, to a cupboard or shelf)										
F-10 Reaching down (eg, to the floor or a shelf)										
F-11 Meal preparation										
F-12 Intimate activity (eg, foreplay, sexual activity)										
A-13 Walking on level surfaces										
A-14 Walking on uneven surfaces										

Independent rating	Independent	Uncomfortable, no change in activity	Decreased ability, no change in manner of performance	Slower, cautious, more careful	Prefer using an object for help	Must use an object for help	Must use special equipment	Need physical assistance	Dependent	Too difficult, no longer

Task	1	2	3	4	5	6	7	8	9	10
A-15 Going up steps										
A-16 Going down steps										
A-17 Walking in narrow spaces (eg, corridor, grocery store aisle)										
A-18 Walking in open spaces										
A-19 Walking in crowds										
A-20 Using an elevator										
A-21 Using an escalator										

Independent rating	Independent	Uncomfortable, no change in activity	Decreased ability, no change in manner of performance	Slower, cautious, more careful	Prefer using an object for help	Must use an object for help	Must use special equipment	Need physical assistance	Dependent	Too difficult, no longer
Task	1	2	3	4	5	6	7	8	9	10
I-22 Driving a car										
I-23 Carrying things while walking (eg, package, garbage bag)										
I-24 Light household chores (eg, dusting, putting items away)										
I-25 Heavy household chores (eg, vacuuming, moving furniture)										
I-26 Active recreation (eg, sports, gardening)										
I-27 Occupational role (eg, job, child care, homemaking, student)										
I-28 Travelling around the community (car, bus)										

APPENDIX 4 Vertigo symptom scale (VSS)

Identification no.:_____Today's date: _____

(DD/MM/YEAR)

VERTIGO SYMPTOM SCALE

The following questions ask about the type of symptoms you experience and how often they occur. Please circle the appropriate number to indicate about how many times you have experienced each of the symptoms listed below during the past month.

0	1	2	3	4
Never	A few times (1-3 times a month)	Several times (4-12 times a month)	Quite often (on average more than 4-7 times a week)	Very often (on average more than once a day)

How often in the past month have you had the following symptoms:

1. A feeling that either you, or things around you, are spinning or moving, lasting (PLEASE ANSWERS ALL THE CATEGORIES)

a.	Less than 2 minutes	0	1	2	3	4
b.	Up to 20 minutes	0	1	2	3	4
c.	20 minutes to one hour	0	1	2	3	4
d.	Several hours	0	1	2	3	4
e.	More than 12 hours	0	1	2	3	4

2. Pains in the heart or chest region

0 1 2 3 4

3. Hot or cold spells

0 1 2 3 4

4. Unsteadiness so severe that you actually fall

0 1 2 3 4

5. Nausea (feeling sick), stomach churning

0 1 2 3 4

6. Tension/soreness in your muscles

0 1 2 3 4

7. A feeling of being light-headed, 'swimmy' or giddy, lasting
(PLEASE ANSWERS ALL THE CATEGORIES)

a.	Less than 2 minutes	0	1	2	3	4
b.	Up to 20 minutes	0	1	2	3	4
c.	20 minutes to one hour	0	1	2	3	4
d.	Several hours	0	1	2	3	4
e.	More than 12 hours	0	1	2	3	4

8. Trembling, shivering

0 1 2 3 4

9. Feeling of pressure in the ear(s)

0 1 2 3 4

10. Heart pounding or fluttering

0 1 2 3 4

11. Vomiting

0 1 2 3 4

12. Heavy feeling in arms or legs

0 1 2 3 4

13. Visual disturbances (e.g. blurring, flickering, spots before the eyes)

0 1 2 3 4

14. Headache or feeling of pressure in the head

0 1 2 3 4

15. Unable to stand or walk properly without support

0 1 2 3 4

16. Difficulty in breathing, short of breath

0 1 2 3 4

17. Loss of concentration or memory

0 1 2 3 4

18. Feeling unsteady, about to lose balance lasting:
(PLEASE ANSWER ALL THE CATEGORIES)

a.	Less than 2 minutes	0	1	2	3	4
b.	Up to 20 minutes	0	1	2	3	4
c.	20 minutes to one hour	0	1	2	3	4
d.	Several hours	0	1	2	3	4
e.	More than 12 hours	0	1	2	3	4

19. Tingling, prickling or numbness in parts of the body

0 1 2 3 4

20. Pains in the lower part of your back

0 1 2 3 4

21. Excessive sweating

0 1 2 3 4

22. Feeling faint, about to black out

0 1 2 3 4

23. Feeling ‘spaced out’, out of touch with your body

0 1 2 3 4

APPENDIX 5 Activities-specific balance confidence (ABC) scale

Identification no. :_____

Today's date : _____ (DD/MM/YEAR)

The Activities-specific Balance Confidence (ABC) Scale

Instructions to Participants:

For each of the following, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady from choosing one of the percentage points on the scale form 0% to 100%. If you do not currently do the activity in question, try and imagine how confident you would be if you had to do the activity. If you normally use a walking aid to do the activity or hold onto someone, rate your confidence as it you were using these supports. If you have any questions about answering any of these items, please ask the administrator.

For each of the following activities, please indicate your level of selfconfidence by choosing a corresponding number from the following rating scale:

0%	10	20	40	50	60	70	80	90	100%
No confidence									Completely confident

"How confident are you that you will not lose your balance or become unsteady when you…

1. …walk around the house? ____%

2. …walk up or down stairs? ____%

3. …bend over and pick up a slipper from the front of a closet floor ____%

4. …reach for a small can off a shelf at eye level? ____%

5. …stand on your tiptoes and reach for something above your head? ____%

6. …stand on a chair and reach for something? ____%

7.…sweepthe floor? ____%

8. …walk outside the house to a car parked in the driveway? ____%

9. …get into or out of a car? ____%

10. …walk across a parking lot to the mall? ____%

11. …walk up or down a ramp? ____%

12. …walk in a crowded mall where people rapidly walk past you? ____%

13. …are bumped into by people as you walk through the mall? ____%

14. … step onto or off an escalator while you are holding onto a railing? ____%

15. … step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing? ____%

16. …walk outside on icy sidewalks? ____%

APPENDIX 6 The dizziness handicap inventory (DHI)

Instructions:

Please tick the best answer for each question regarding your dizziness and/or unsteadiness problems, specifically considering your condition during the last month.

P1	Does looking up increase your problem?	○ Yes ○ Sometimes ○ No
E2	Because of your problem, do you feel frustrated?	○ Yes ○ Sometimes ○ No
F3	Because of your problem, do you restrict your travel for business or recreation?	○ Yes ○ Sometimes ○ No
P4	Does walking down the aisle of a supermarket increase your problems?	○ Yes ○ Sometimes ○ No
F5	Because of your problem, do you have difficulty getting into or out of bed?	○ Yes ○ Sometimes ○ No
F6	Does your problem significantly restrict your participation in social activities, such as going out to dinner, going to the movies, dancing, or going to parties?	○ Yes ○ Sometimes ○ No
F7	Because of your problem, do you have difficulty reading?	○ Yes

- Sometimes
- No

P8 Does performing more ambitious activities such as sports, dancing, household chores (sweeping or putting dishes away) increase your problems?

- Yes
- Sometimes
- No

E9 Because of your problem, are you afraid to leave your home without having without having someone accompany you?

- Yes
- Sometimes
- No

E10 Because of your problem have you been embarrassed in front of others?

- Yes
- Sometimes
- No

P11 Do quick movements of your head increase your problem?

- Yes
- Sometimes
- No

F12 Because of your problem, do you avoid heights?

- Yes
- Sometimes
- No

P13 Does turning over in bed increase your problem?

- Yes
- Sometimes
- No

F14 Because of your problem, is it difficult for you to do strenuous homework or yard work?

- Yes
- Sometimes
- No

E15 . Because of your problem, are you afraid people may think you are intoxicated?

- Yes

- Sometimes
- No

F16 Because of your problem, is it difficult for you to go for a walk by yourself?

- Yes
- Sometimes
- No

P17 Does walking down a sidewalk increase your problem?

- Yes
- Sometimes
- No

E18 Because of your problem, is it difficult for you to concentrate

- Yes
- Sometimes
- No

F19 Because of your problem, is it difficult for you to walk around your house in the dark?

- Yes
- Sometimes
- No

E20 Because of your problem, are you afraid to stay home alone?

- Yes
- Sometimes
- No

E21 Because of your problem, do you feel handicapped?

- Yes
- Sometimes
- No

E22 Has the problem placed stress on your relationships with members of your family or friends?

- Yes
- Sometimes
- No

E23 Because of your problem, are you depressed?

- Yes

- Sometimes
- No

F24 Does your problem interfere with your job or household responsibilities?

- Yes
- Sometimes
- No

P25 Does bending over increase your problem?

- Yes
- Sometimes
- No

APPENDIX 7 Illness behaviour questionnaire (Form A)

Identification number:_____

Date: _____

This questionnaire collects information about your illness and how it affects you.

Please circle an appropriate answer for each question.

ILLNESS BEHAVIOUR QUESTIONNAIRE (IBQ)

No.	Items	Answer	
1	Do you worry a lot about your health?	Yes	No
2	Do you think there is something seriously wrong with your body?	Yes	No
3	Does your illness interfere with your life a great deal?	Yes	No
4	Are you easy to get on with when you are ill?	Yes	No
5	Does your family have a history of illness?	Yes	No
6	Do you think you are more liable to illness than other people?	Yes	No
7	If the doctor told you that he could find nothing wrong with you would you believe him?	Yes	No
8	Is it easy for you to forget about yourself and think about all sorts of other things?	Yes	No
9	If you feel ill and someone tells you that you are looking better, do you become annoyed?	Yes	No

10	Do you find that you are often aware of various things happening in your body?	Yes	No
11	Do you ever think of your illness as a punishment for something you have done wrong in the past?	Yes	No
12	Do you have trouble with your nerves?	Yes	No
13	If you feel ill or worried, can you be easily cheered up by the doctor?	Yes	No
14	Do you think that other people realise what its like to be sick?	Yes	No
15	Does it upset you to talk to the doctor about your illness?	Yes	No
16	Are you bothered by many pains and aches?	Yes	No
17	Does your illness affect the way you get on with your family or friends a great deal?	Yes	No
18	Do you find that you get anxious easily?	Yes	No
19	Do you know anybody who has had the same illness as you?	Yes	No
20	Are you more sensitive to pain than other people?	Yes	No
21	Are you afraid of illness?	Yes	No
22	Can you express your personal feelings easily to other people?	Yes	No

23	Do people feel sorry for you when you are ill?	Yes	No
24	Do you think that you worry about your health more than most people?	Yes	No
25	Do you find that your illness affects your sexual relations?	Yes	No
26	Do you experience a lot of pain with your illness?	Yes	No
27	Except for your illness, do you have any problems in your life?	Yes	No
28	Do you care whether or not people realise you are sick?	Yes	No
29	Do you find that you get jealous of other people's good health?	Yes	No
30	Do you ever have silly thoughts about your health which you can't get out of your mind, no matter how hard you try?	Yes	No
31	Do you have any financial problems?	Yes	No
32	Are you upset by the way people take your illness?	Yes	No
33	Is it hard for you to believe the doctor when he tells you there is nothing for you to worry about?	Yes	No
34	Do you often worry about the possibility that you have got a serious illness?	Yes	No

35	Are you sleeping well?	Yes	No
36	When you are angry, do you tend to bottle up your feelings?	Yes	No
37	Do you often think that you might suddenly fall ill?	Yes	No
38	If a disease is brought to your attention (through the radio, television, newspapers or someone you know) do you worry about getting it yourself?	Yes	No
39	Do you get the feeling that people are not taking your illness seriously enough?	Yes	No
40	Are you upset by the appearance of your face or body?	Yes	No
41	Do you find that you are bothered by many different symptoms?	Yes	No
42	Do you frequently try to explain to others how you are feeling?	Yes	No
43	Do you have any family problems?	Yes	No
44	Do you think there is something the matter with your mind?	Yes	No
45	Are you eating well?	Yes	No
46	Is your bad health the biggest difficulty of your life?	Yes	No
47	Do you find that you get sad easily?	Yes	No

48	Do you worry or fuss over small details that seem unimportant to others?	Yes	No
49	Are you always a co-operative patient?	Yes	No
50	Do you often have the symptoms of a very serious disease?	Yes	No
51	Do you find that you get angry easily?	Yes	No
52	Do you have any work problems?	Yes	No
53	Do you prefer to keep your feelings to yourself?	Yes	No
54	Do you often find that you get depressed?	Yes	No
55	Would all your worries be over if you were physically healthy?	Yes	No
56	Are you more irritable towards other people?	Yes	No
57	Do you think that your symptoms may be caused by worry?	Yes	No
58	Is it easy for you to let people know when you are cross with them?	Yes	No
59	Is it hard for you to relax?	Yes	No
60	Do you have personal worries which are not caused by physical illness?	Yes	No
61	Do you often find that you lose patience with other people?	Yes	No
62	Is it hard for you to show people your personal feelings?	Yes	No

APPENDIX 8 Illness behaviour questionnaire (From B)

Identification number:_____

Date: _____

This questionnaire collects information about your illness and how it affects you.

Please circle an appropriate answer for each question.

ILLNESS BEHAVIOUR QUESTIONNAIRE (IBQ)

No.	Items	Answer	
1	Do you worry a lot about your health?	Yes	No
2	Do you think there is something seriously wrong with your body?	Yes	No
3	Do you have an illness which interfere with your life a great deal?	Yes	No
4	Are you easy to get on with when you are ill?	Yes	No
5	Does your family have a history of illness?	Yes	No
6	Do you think you are more liable to illness than other people?	Yes	No
7	If the doctor told you that he could find nothing wrong with you would you believe him?	Yes	No
8	Is it easy for you to forget about yourself and think about all sorts of other things?	Yes	No
9	If you feel ill and someone tells you that you are looking better, do you become annoyed?	Yes	No

10	Do you find that you are often aware of various things happening in your body?	Yes	No
11	Do you ever think that you have an which is a punishment for something you have done wrong in the past?	Yes	No
12	Do you have trouble with your nerves?	Yes	No
13	If you feel ill or worried, can you be easily cheered up by the doctor?	Yes	No
14	Do you think that other people realise what its like to be sick?	Yes	No
15	Does it upset you to talk to the doctor about illness?	Yes	No
16	Are you bothered by many pains and aches?	Yes	No
17	Do you have an illness which affects the way you get on with your family or friends a great deal?	Yes	No
18	Do you find that you get anxious easily?	Yes	No
19	Do you have an illness which is the same as anybody you know has had?	Yes	No
20	Are you more sensitive to pain than other people?	Yes	No
21	Are you afraid of illness?	Yes	No
22	Can you express your personal feelings easily to other people?	Yes	No

23	Do people feel sorry for you when you are ill?	Yes	No
24	Do you think that you worry about your health more than most people?	Yes	No
25	Do you have an illness which affects your sexual relations?	Yes	No
26	Do you have an illness with a lot of pain?	Yes	No
27	Except for illness, do you have any problems in your life?	Yes	No
28	Do you care whether or not people realise when you are sick?	Yes	No
29	Do you find that you get jealous of other people's good health?	Yes	No
30	Do you ever have silly thoughts about your health which you can't get out of your mind, no matter how hard you try?	Yes	No
31	Do you have any financial problems?	Yes	No
32	Are you upset by the way people take your illness when you are sick?	Yes	No
33	Is it hard for you to believe the doctor when he tells you there is nothing for you to worryabout?	Yes	No
34	Do you often worry about the possibility that you have got a serious disease?	Yes	No
35	Are you sleeping well?	Yes	No

36	When you are angry, do you tend to bottle up your feelings?	Yes	No
37	Do you often think that you might suddenly fall ill?	Yes	No
38	If a disease is brought to your attention (through the radio, television, newspapers orsomeone you know) do you worry about getting it yourself?	Yes	No
39	Do you get the feeling that people are not taking your illness seriously enough when you are sick?	Yes	No
40	Are you upset by the appearance of your face or body?	Yes	No
41	Do you find that you are bothered by many different symptoms?	Yes	No
42	Do you frequently try to explain to others how you are feeling?	Yes	No
43	Do you have any family problems?	Yes	No
44	Do you think there is something the matter with your mind?	Yes	No
45	Are you eating well?	Yes	No
46	Is bad health the biggest difficulty of your life?	Yes	No
47	Do you find that you get sad easily?	Yes	No
48	Do you worry or fuss over small details that seem unimportant to others?	Yes	No

49	Are you always a cooperative patient?	Yes	No
50	Do you often have the symptoms of a serious disease?	Yes	No
51	Do you find that you get angry easily?	Yes	No
52	Do you have any work problems?	Yes	No
53	Do you prefer to keep your feelings to yourself?	Yes	No
54	Do you often find that you get depressed?	Yes	No
55	Would all your worries be over if you were physically healthy?	Yes	No
56	Are you more irritable towards other people?	Yes	No
57	Do you have symptoms may be caused by worry?	Yes	No
58	Is it easy for you to let people know when you are cross with them?	Yes	No
59	Is it hard for you to relax?	Yes	No
60	Do you have personal worries which are not caused by physical illness?	Yes	No
61	Do you often find that you lose patience with other people?	Yes	No
62	Is it hard for you to show people your personal feelings?	Yes	No

APPENDIX 9 Functional Gait Assessment (FGA)

Identification no. _____

Date : _____

Requirements: A marked 6-m (20-ft) walkway that is marked with a 30.48-cm (12-in) width.

_____**1. GAIT LEVEL SURFACE**

Instructions: *Walk at your normal speed from here to the next mark (6 m [20 ft]).*

Grading: Mark the highest category that applies.

(3) Normal—Walks 6 m (20 ft) in less than 5.5 seconds, no assistive devices, good speed, no evidence for imbalance, normal gait pattern, deviates no more than 15.24 cm (6 in) outside of the 30.48-cm (12-in) walkway width.

(2) Mild impairment—Walks 6 m (20 ft) in less than 7 seconds but greater than 5.5 seconds, uses assistive device, slower speed, mild gait deviations, or deviates 15.24–25.4 cm (6–10 in) outside of the 30.48-cm (12-in) walkway width.

(1) Moderate impairment—Walks 6 m (20 ft), slow speed, abnormal gait pattern, evidence for imbalance, or deviates 25.4–
38.1 cm (10–15 in) outside of the 30.48-cm (12-in) walkway width. Requires more than 7 seconds to ambulate 6 m (20 ft).

(0) Severe impairment—Cannot walk 6 m (20 ft) without assistance, severe gait deviations or imbalance, deviates greater than 38.1 cm (15 in) outside of the 30.48-cm (12-in) walkway width or reaches and touches the wall.

_____**2. CHANGE IN GAIT SPEED**

Instructions: *Begin walking at your normal pace (for 1.5 m [5 ft]). When I tell you "go," walk as fast as you can (for 1.5 m [5 ft]). When I tell you "slow," walk as slowly as you can (for 1.5 m [5 ft]).*

Grading: Mark the highest category that applies.

(3) Normal—Able to smoothly change walking speed without loss of balance or gait deviation. Shows a significant difference inwalking speeds between normal, fast, and slow speeds.Deviates no more than 15.24 cm (6 in) outside of the 30.48-cm (12-in) walkway width.

(2) Mild impairment—Is able to change speed but demonstrates mild gait deviations, deviates 15.24–25.4 cm (6–10 in) outsideof the 30.48-cm (12-in) walkway width, or no gait deviations but unable to achieve a significant change in velocity, or uses an
assistive device.

(1) Moderate impairment—Makes only minor adjustments to walking speed, or accomplishes a change in speed with significantgait deviations, deviates 25.4–38.1 cm (10–15 in) outside the 30.48-cm (12-in) walkway width, or changes speed but loses balance but is able to recover and continue walking.

(0) Severe impairment—Cannot change speeds, deviates greater than 38.1 cm (15 in) outside 30.48-cm (12-in) walkway width,or loses

balance and has to reach for wall or be caught.

_____3. GAIT WITH HORIZONTAL HEAD TURNS

Instructions: *Walk from here to the next mark 6 m (20 ft) away. Begin walking at your normal pace. Keep walking straight; after 3 steps, turn your head to the right and keep walking straight while looking to the right. After 3 more steps, turn your head to the left and keep walking straight while looking left. Continue alternating looking right and left every 3 steps until you have completed 2 repetitions in each direction.*

Grading: Mark the highest category that applies.

(3) Normal—Performs head turns smoothly with no change in gait. Deviates no more than 15.24 cm (6 in) outside 30.48-cm (12-in) walkway width.

(2) Mild impairment—Performs head turns smoothly with slight change in gait velocity (eg, minor disruption to smooth gaitpath), deviates 15.24–25.4 cm (6–10 in) outside 30.48-cm (12-in) walkway width, or uses an assistive device.

(1) Moderate impairment—Performs head turns with moderate change in gait velocity, slows down, deviates 25.4–38.1 cm(10–15 in) outside 30.48-cm (12-in) walkway width but recovers, can continue to walk.

(0) Severe impairment—Performs task with severe disruption of gait (eg, staggers 38.1 cm [15 in] outside 30.48-cm (12-in) walkway width, loses balance, stops, or reaches for wall).

_____4. GAIT WITH VERTICAL HEAD TURNS

Instructions: *Walk from here to the next mark (6 m [20 ft]). Begin walking at your normal pace. Keep walking straight; after 3 steps, tip your head up and keep walking straight while looking up. After 3 more steps, tip your head down, keep walking straight while looking down. Continue alternating looking up and down every 3 steps until you have completed 2 repetitions in each direction.*

Grading: Mark the highest category that applies.

(3) Normal—Performs head turns with no change in gait. Deviates no more than 15.24 cm (6 in) outside 30.48-cm (12-in) walkway width.

(2) Mild impairment—Performs task with slight change in gait velocity (eg, minor disruption to smooth gait path), deviates15.24–25.4 cm (6–10 in) outside 30.48-cm (12-in) walkway width or uses assistive device.

(1) Moderate impairment—Performs task with moderate change in gait velocity, slows down, deviates 25.4–38.1 cm (10–15 in)outside 30.48-cm (12-in) walkway width but recovers, can continue to walk.

(0) Severe impairment—Performs task with severe disruption of gait (eg, staggers 38.1 cm [15 in] outside 30.48-cm (12-in) walkway width, loses balance, stops, reaches for wall).

_____**5. GAIT AND PIVOT TURN**
Instructions: *Begin with walking at your normal pace. When I tell you,"turn and stop," turn as quickly as you can to face the opposite direction and stop.*

Grading: Mark the highest category that applies.

(3) Normal—Pivot turns safely within 3 seconds and stops quickly with no loss of balance.

(2) Mild impairment—Pivot turns safely in _3 seconds and stops with no loss of balance, or pivot turns safely within 3 secondsand stops with mild imbalance, requires small steps to catch balance.

(1) Moderate impairment—Turns slowly, requires verbal cueing, or requires several small steps to catch balance following turn and stop.

(0) Severe impairment—Cannot turn safely, requires assistance to turn and stop.

_____**6. STEP OVER OBSTACLE**
Instructions: *Begin walking at your normal speed. When you come to the shoe box, step over it, not around it, and keep walking.*

Grading: Mark the highest category that applies.

(3) Normal—Is able to step over 2 stacked shoe boxes taped together (22.86 cm [9 in] total height) without changing gaitspeed; no evidence of imbalance.

(2) Mild impairment—Is able to step over one shoe box (11.43 cm [4.5 in] total height) without changing gait speed; no evidence of imbalance.

(1) Moderate impairment—Is able to step over one shoe box (11.43 cm [4.5 in] total height) but must slow down and adjust steps to clear box safely. May require verbal cueing.

(0) Severe impairment—Cannot perform without assistance.

_____**7. GAIT WITH NARROW BASE OF SUPPORT**
Instructions: *Walk on the floor with arms folded across the chest, feet aligned heel to toe in tandem for a distance of 3.6 m [12 ft]. The number of steps taken in a straight line are counted for a maximum of 10 steps.*

Grading: Mark the highest category that applies.

(3) Normal—Is able to ambulate for 10 steps heel to toe with no staggering.

(2) Mild impairment—Ambulates 7–9 steps.

(1) Moderate impairment—Ambulates 4–7 steps.

(0) Severe impairment—Ambulates less than 4 steps heel to toe or cannot perform without assistance.

_____**8. GAIT WITH EYES CLOSED**
Instructions: *Walk at your normal speed from here to the next mark (6 m [20 ft]) with your eyes closed.*

Grading: Mark the highest category that applies.

(3) Normal—Walks 6 m (20 ft), no assistive devices, good speed, no evidence of imbalance, normal gait pattern, deviates no more than 15.24 cm (6 in) outside 30.48-cm

(12-in) walkway width. Ambulates 6 m (20 ft) in less than 7 seconds.

(2) Mild impairment—Walks 6 m (20 ft), uses assistive device, slower speed, mild gait deviations, deviates 15.24–25.4 cm(6–10 in) outside 30.48-cm (12-in) walkway width. Ambulates 6 m (20 ft) in less than 9 seconds but greater than 7 seconds.

(1) Moderate impairment—Walks 6 m (20 ft), slow speed, abnormal gait pattern, evidence for imbalance, deviates 25.4–38.1cm (10–15 in) outside 30.48-cm (12-in) walkway width. Requires more than 9 seconds to ambulate 6 m (20 ft).

(0) Severe impairment—Cannot walk 6 m (20 ft) without assistance, severe gait deviations or imbalance, deviates greater than 38.1cm (15 in) outside 30.48-cm (12-in) walkway width or will not attempt task.

_____**9. AMBULATING BACKWARDS**

Instructions: *Walk backwards until I tell you to stop.*

Grading: Mark the highest category that applies.

(3) Normal—Walks 6 m (20 ft), no assistive devices, good speed, no evidence for imbalance, normal gait pattern, deviates nomore than 15.24 cm (6 in) outside 30.48-cm (12-in) walkway width.

(2) Mild impairment—Walks 6 m (20 ft), uses assistive device, slower speed, mild gait deviations, deviates 15.24–25.4 cm(6–10 in) outside 30.48-cm (12-in) walkway width.

(1) Moderate impairment—Walks 6 m (20 ft), slow speed, abnormal gait pattern, evidence for imbalance, deviates 25.4–38.1cm (10–15 in) outside 30.48-cm (12-in) walkway width.

(0) Severe impairment—Cannot walk 6 m (20 ft) without assistance, severe gait deviations or imbalance, deviates greater than 38.1 cm (15 in) outside 30.48-cm (12-in) walkway width or will not attempt task.

_____**10. STEPS**

Instructions: *Walk up these stairs as you would at home (ie, using the rail if necessary). At the top turn around and walk down.*

Grading: Mark the highest category that applies.

(3) Normal—Alternating feet, no rail.

(2) Mild impairment—Alternating feet, must use rail.

(1) Moderate impairment—Two feet to a stair; must use rail.

(0) Severe impairment—Cannot do safely.

TOTAL SCORE: _____ /30

APPENDIX 10 Time Up and Go Test (TUG)

Example of TUG protocol and instruction

Timed Up and Go (TUG) Test[1,2]

1. Equipment: arm chair, tape measure, tape, stop watch.

2. Begin the test with the subject sitting correctly in a chair with arms, the subject's back should resting on the back of the chair. The chair should be stableand positioned such that it will not move when the subject moves from sitting to standing.

3. Place a piece of tape or other marker on the floor 3 meters away from the chair so that it is easily seen by the subject.

4. Instructions : "On the word *GO* you will stand up, walk to the line on the floor, turn around and walk back to the chair and sit down. Walk at your regular pace.

5. Start timing on the word "*GO*" and stop timing when the subject is seated again correctly in the chair with their back resting on the back of the chair.

6. The subject wears their regular footwear, may use any gait aid that they normally use during ambulation, but may not be assisted by another person. There is no time limit. They may stop and rest (but not sit down) if they need to.

7. Normal healthy elderly usually complete the task in ten seconds or less. Very frail or weak elderly with poor mobility may take 2 minutes or more.

8. The subject should be given a practice trial that is not timed before testing.

9. Results correlate with gait speed, balance, functional level,the ability to go out, and can follow change over time.

10. Interpretation ≤ 10 seconds = normal

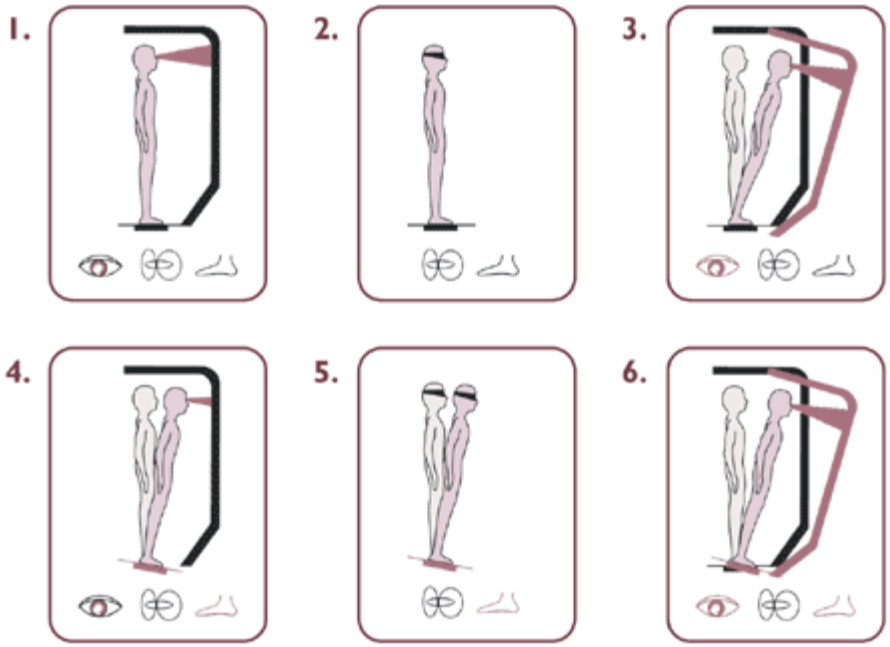
≤ 20 seconds = good mobility, can go out alone, mobile without a gait aid.

< 30 seconds = problems, cannot go outside alone, requires a gait aid.

A score of more than or equal to fourteen seconds has been shown to indicate high risk of falls.

1. Podsiadlo D, Richardson S. *The Time "Up & Go": A Test of Basic Functional Mobility for Frail Elderly Persons.* Journal of the American Geriatrics Society 1991; 39(2): 142-148
2. Shumway - Cook A, Brauer S, Woollacott M. *Predicting the Probability for Falls in Community-Dwelling Older Adults Using the Timed Up & Go Test.* Physical Therapy 2000 Vol 80(9): 896-903.
Saskatoon Falls Prevention Consortium, Falls Screening and Referral Algorithm, TUG, Saskatoon Falls Prevention consortium, June, 2005

APPENDIX 11 Computerised dynamic posturography



Computerised dynamic posturography: Sensory organisation test (SOT)

Testing is performed under six different sensory conditions:

1. Subjects stand on a stationary support surface with eyes open, fixed visual surround

2. Subjects stand on a stationary support surface with eyes closed

3. Subject stand on a stationary support surface with sway-referenced vision

4. Subject stand on a sway reference support surface with eyes open, fixed visual surround

5. Subject stand on a sway reference support surface with eyes closed

6. Subject stand on a sway reference support surface with eyes open, sway visual surround

APPENDIX 12 Information sheet (Study 1-Healthy participant)

INFORMATION SHEET FOR PARTICIPANTS

REC ReferenceNumber: BDM/09/10-56

YOU WILL BE GIVEN A COPY OF THIS INFORMATION SHEET

Study of free walking of healthy individuals using data from triaxial accelerometer sensors.

We would like to invite you to participate in thispostgraduate research project. You should only participate if you want to; choosing not to take part will not disadvantage you in any way. Before you decide whether you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information.

We are studying the way people walk in everyday environments, such as climbing stairs, walking in quiet and busy environments, and crossing the road. To do this we would like to ask volunteers who are willing to go for a kilometre (km)-long walk in the London Bridge area following a set route. We would like to gather by using sensor boxes (match size box) placed on a small of the back, neck and on the head. This type of sensor has already been used for assessing standing, walking and stair climbing with older persons in a laboratory environment but we would like now to test it in free walking. We would also like to do some basic tests about your general level of function. We need volunteers between the ages of 18 and 65 years who can perform all activities of daily living (e.g. walk outdoors, go up and down stairs, cross the road etc.) independently

You will be asked to do the following:

Sign the consent form and complete a screening questionnaire.

Get up from a chair, walk ahead three meters and return to the chair in order to assess how long these daily tasks take you to complete.

Complete a 10-item test which assesses walking ability during different tasks such as walking at different speeds, over an obstacle, or with simultaneous head movements.

Walk following a set route in the London Bridge area, in the middle of morning or afternoon. For this you will be asked to wear a small sensor box stuck to the skin at the small of your back, at the neck level and on your head hidden in a hat. You will also be asked to carry a data logger and light weight notebook in a backpack. You will be followed by at least one researcher to help you in case you need assistance. You can wear your usual clothing and shoes but please avoid high heels and also please DO NOT drink alcohol for 24 hours before the test.

The test can be arranged for a day and session that is convenient for you. You will have to come to Guy's Campus of King's College London, in London Bridge, London

SE1 1UL. Your travel costs will be reimbursed. The entire tests will take approximately one and half hours.

During the test there are risks of falling and dealing with traffic but they should not be greater than the risks you face during your daily activities. We will use a hypoallergenic adhesive tape to fix the sensor on the skin at the small of your back and neck. We will use a spray under the adhesive that will help it to come off easily when the test is finished. There might be some discomfort (similar to taking off sticking plaster) when the sensor comes off but there should be no lasting damage or irritation to the skin. There is also a risk of having an allergic reaction to the adhesive tape. If you have an allergy to adhesives, please inform the staff before the test.

All data will be treated in confidence, no names will be mentioned in any of the reports of the study and care will be taken so that individuals cannot be identified from details in reports and publications of the study. It is up to you to decide whether to take part or not. If you decide to take part you are still free to withdraw at any time and without giving a reason.

If this study has harmed you in any way you can contact King's College London using the details below for further advice and information:

1.MsMarniza Omar (PhD student)

Division of Applied Biomedical Research,

Room 3.11 Shepherd's House,

Guy's Campus, King's College London,

London SE1 1UL.

Office: 02078486679

Email: marniza.omar@kcl.ac.uk

2. Dr MarousaPavlou PhD BA MCSP (Supervisor)

King's College London

School of Biomedical and Health Sciences

Academic Dept of Physiotherapy

Shepherd's House

Guy's Campus

London

SE1 1UL

Office: 02078486328

Email: marousa.pavlou@kcl.ac.uk

APPENDIX 13 Consent form (Study 1)

CONSENT FORM FOR PARTICIPANTS IN RESEARCH STUDIES

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

Title of Study: Study of free walking of healthy individuals using data from triaxial accelerometer sensors

King's College Research Ethics Committee Ref: BDM/09/10-56

Thank you for considering taking part in this research. The person organising the research must explain the project to you before you agree to take part.

If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.

I understand that if I decide at any time during the research that I no longer wish to participate in this project, I can notify the researchers involved and withdraw from it immediately without giving any reason. Furthermore, I understand that I will be able to withdraw my data up to (the point of publication or up until the point stated on the Information Sheet).

I consent to the processing of my personal information for the purposes explained to me. I understand that such information will be handled in accordance with the terms of the Data Protection Act 1998.

Participant's Statement:

I -

_____

agree that the research project named above has been explained to me to my satisfaction and I agree to take part in the study. I have read both the notes written above and the Information Sheet about the project, and understand what the research study involves.

Signed Date

APPENDIX 14 Information sheet for patient (Study 1)

University College London Hospitals NHS
NHS Trust

The National Hospital for Neurology and Neurosurgery

Department of Neuro-otology

Box 127

Queen Square, London

WC1N 3BG

INFORMATION SHEET FOR PARTICIPANTS

Study of free walking in patients with a peripheral vestibular disorder

YOU WILL BE GIVEN A COPY OF THIS INFORMATION SHEET

You are being invited to take part in a research project. Here is some information to help you decide whether or not to take part. Before you decide whether you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information carefully and discuss it with friends, relatives and your GP if you wish. Please do not hesitate to ask us if there is anything you do not understand or if you would like more information. Please do take time to decide whether you wish to take part. You should only participate if you want to; choosing not to take part will not disadvantage you in any way.

Background

It has been shown that individuals with balance disorders arising from the inner ear may feel more unsteady when walking, particularly in busy environments (i.e. crowds) or on uneven surfaces. Patients may also have difficulty maintaining their balance when moving their head while walking and may also experience unpleasant feelings of motion or blurred vision when walking or turning their head. It has also been shown that patients show changes in walking style compared to healthy adults without a balance disorder.

However these studies have been conducted in a closed laboratory setting, which is very different to walking during daily activities in a real outdoor environment. Therefore these studies may not provide a true indication of the walking of patients with balance problems in everyday life.

What is the purpose of this study?

Until recently it was not possible to assess walking in real environments because measuring instruments had not been developed. Now howevertheuse of matchbox-size sensor-boxes placed at the small of the back and on back of the head are able to record walking in a wide variety of real environments in healthy adults. Therefore the aim of this study is to use this technique to assess balance strategies used by patients with inner ear balance disorders when walking in five common urban environments including an area with a checkerboard floor pattern, a darker area, a busy section, a quiet section, and on an uneven surface (cobbled pathway). This information will be used to develop advances in rehabilitation for patients with inner ear balance disorders.

Why have I been chosen?

You have been asked to participate in this study because you are between 18-65 years of age and have been diagnosed with a peripheral inner ear balance disorder. You have been referred by your consultant physician.

Do I have to take part?

It is up to you to decide whether to take part. We will describe the study to you and then go through this information sheet. If you agree to participate we will ask you to give your verbal consent and sign a consent form to show that you have agreed to take part. You are free to withdraw at any time without giving a reason. This will not affect the standard of care you receive.

What will happen to me if I take part?

If you decide to participate, you will be asked to attend the Academic Department of Physiotherapy, King's College London based at London Bridge, London SE1 1UL for a single visit to complete a brief set of questionnaires, two short walking tests in the laboratory, and the outdoor walking test. The brief set of questionnaires will ask about particular symptoms and their severity (for example, feelings of unsteadiness), the situations that may produce these symptoms (for example, crowds), emotional state, the ability to perform various daily activities, and confidence in your ability to maintain balance in everyday activities.

The indoor balance tests will look at your normal walking speed and your ability to maintain your balance in standing or while walking during different conditions, such as when the surface is unsteady or when you move your head at the same time.

The outdoor walking test will involve following a set route in the London Bridge area, in the middle of the morning or the afternoon. We would like to gather data by using sensor boxes placed at the small of your back, at the neck level and on the head (hidden in a hat) which are about the size of match box. You will also carry a wireless data logger in a pouch or pocket. You will be followed by two researchers to help you in case you need assistance. You can wear your usual clothing and shoes but please avoid high heels and also please **DO NOT** drink alcohol for 24 hours before the test.

The test can be arranged for a day and session that is convenient for you. Your travel costs will be reimbursed. The total test will take approximately two hours and 30 minutes.

Are there any risks to me from taking part?

You may, on occasions feel unsteady while performing some of the more challenging walking tasks and when undertaking the balance tests. There are risks of falling and risks handling traffic but they should not be greater than the risks you face during your daily activities. You will be closely supervised throughout when performing all tests. If you feel particularly unsteady at any point you can stop the test.

Hypoallergenic adhesive tape will be used to fix the sensor on the skin at the small of your back and on the base of your neck. We will use a spray under the adhesive that will help it to come off easily when the test is finished. There might be some discomfort (similar to taking off sticking plaster) when the sensor comes off but there should be no lasting damage or irritation to the skin. There is also a risk of having an allergic reaction to the adhesive tape. If you have an allergy to adhesives, please inform the staff before the test.

What are the benefits of taking part?

We cannot promise we will be able to help you, but, the extended assessment may help provide further information about the specific balance strategies patients use when walking in challenging outdoor environments. The information from this study will be used to develop an advanced vestibular rehabilitation programme.

Will my taking part be kept confidential?

All information that is collected about you during the course of this research will be kept strictly confidential. All information for this project will be stored on password-protected computers used only by research staff. Any documents leaving the hospital or testing site will have all personal identifiable information removed.

Will my GP or Medical team know about my participation and results of this investigation?

With your permission we would like to share this information with your referring medical team. Your GP will not be informed of your participation in this study.

Will this affect my current treatment?

Participating in this study will not affect your current treatment.

What happens if there is a problem?

This study has been reviewed and accepted by the National Hospital for Neurology and Neurosurgery and Institute of Neurology Joint Ethics Committee. The consultant in charge

of this investigation is Dr Doris Eva Bamiou (Consultant in Audiological Medicine, NHNN). Other investigators conducting this study are Professor Linda Luxon, Professor in Audiovestibular Medicine and Consultant Neuro-otological Physician at NHNN, Dr.MarousaPavlou (Lecturer in Physiotherapy, King's College London), Dr Ruth Mayagoitia-Hill (Lecturer in assistive technology, King's College London) and Mrs. Marniza Omar (Audiologist, PhD student at King's College London).

If you have any concerns regarding the study please contact Dr MarousaPavlou, the physiotherapist who will be leading the testing and who will try to answer your questions (contact details below). If you are unhappy and wish to complain formally, you can do this through the NHS complaints procedure. Details can be obtained from the hospital.

In the event that something does go wrong and you are harmed during the research and this is due to someone's negligence, then you may have grounds for legal action for compensation against University College London Hospitals NHS Trust, but you may have to pay for legal costs. The normal NHS complaints procedure will still be available to you.

It is up to you to decide whether to take part or not. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect the treatment you receive from your medical or therapy team in any way. You may withdraw your data from the project at any time up until it is transcribed for use in the final report in December 2010.

If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. Your data will be kept anonymously and will not be passed on outside of your medical care team.

Who can I contact for further information?

If you have any queries please contact Dr MarousaPavlou, the Physiotherapist leading the testing for this study.

Dr MarousaPavlou PhD BA MCSP

King's College London

School of Biomedical and Health Sciences

Academic Dept of Physiotherapy

Shepherd's House

Guy's Campus

London

SE1 1UL

Phone: office: 02078486328; mobile: 07834406530

Email: marousa.pavlou@kcl.ac.uk

APPENDIX 15 Consent form (Study 1)

CONSENT FORM

University College London Hospitals NHS
NHS Trust

Centre Number: UCLH Project ID number:

Patient Identification Number for this study: Form version:

Title of project: Study of free walking in patients with a peripheral vestibular disorder.

Name of Chief Investigator: Dr. Doris-Eva Bamiou,

Consultant in Audiological Medicine, National Hospital for Neurology and Neurosurgery (University College London NHS trust) and Senior Lecturer, Ear Institute (University College London)

Please initial box

1. I confirm that I have read and understood the information sheet dated …….. (version ……..) for the above study and have had the opportunity to ask questions. ☐

2. I confirm that I have had sufficient time to consider whether or not I want to be included in the study ☐

3. I understand that my participation in this study is voluntary and that I am free to withdraw at any time, without giving any reason, and without my medical care or legal rights being affected. ☐

4. I understand that sections of my medical notes may be looked at by responsible individuals from King's College London, The National Hospital for Neurology and Neurosurgery or from regulatory authorities where it is relevant to my taking part in research. I give permission for these individuals to have access to my records. ☐

5. I agree to take part in the above study. ☐

Centre Number: UCLH Project ID number:

Patient Identification Number for this study: Form version:

CONSENT FORM

Title of project: Study of free walking in patients with a peripheral vestibular disorder.

Name of Principal investigator: Dr. Doris-Eva Bamiou,

Consultant in Audiological Medicine, National Hospital for Neurology and Neurosurgery (University College London NHS trust) and Senior Lecturer, Ear Institute (University College London).

Name of patient	Date	Signature
Name of Person taking consent (if different from researcher)	Date	Signature
Researcher (to be contacted if there are any problems)	Date	Signature

Comments or concerns during the study

If you have any comments or concerns you may discuss these with the investigator. If you wish to go further and complain about any aspect of the way you have been approached or treated during the course of the study, you should write or get in touch with the Complaints Manager, UCL hospitals. Please quote the UCLH project number at the top this consent form.

APPENDIX 16 Information sheet for people with stroke (Study 2)

University College London Hospitals NHS
NHS Trust

The National Hospital for Neurology and Neurosurgery

Department of Neuro-otology

Box 127

Queen Square, London

WC1N 3BG

INFORMATION SHEET FOR PARTICIPANTS

Study of free walking in patients with stroke

YOU WILL BE GIVEN A COPY OF THIS INFORMATION SHEET

You are being invited to take part in a research project. Here is some information to help you decide whether or not to take part. Before you decide whether you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information carefully and discuss it with friends, relatives and your GP if you wish. Please do not hesitate to ask us if there is anything you do not understand or if you would like more information. Please do take time to decide whether you wish to take part. You should only participate if you want to; choosing not to take part will not disadvantage you in any way.

Background

Walking ability is significantly limited in many people with stroke, with some experiencing falls while moving from one place to another. Several stroke patients have also reported that they feel more unsteady when walking, particularly in busy environments (i.e. crowds) or on uneven surfaces. Decreased speed and walking capacity in addition to balance deficits have been shown to largely contribute to the increased falls rate and decreased ability to walk in the community after stroke. Patients may also have difficulty maintaining their balance when moving their head while crossing the road for example, and may also experience unpleasant feelings of motion or blurred vision when walking or turning their head.

The different tests used to examine community walking abilities in people with stroke are often performed in laboratory based or hospital environments, which are very different to walking in a real outdoor environment. Therefore these tests may not provide a true indication of the walking abilities or the strategies used by stroke patients with balance problems in everyday life. It is important to identify how different environments affect the ability people with stroke to manage their balance when walking.

What is the purpose of this study?

Until recently it was not possible to assess walking in real environments because measuring instruments had not been developed. Now howeverthe use of matchbox-size sensor-boxes placed on back of the head and the small of the back are able to record how the body moves when walking in a wide variety of real environments. Therefore the aim of this study is to use this technique to assess balance strategies used by patients with walking deficits after stroke, when walking in five common urban environments; an area with a checkerboard floor pattern, a darker area, a busy section, a quiet section, and on an uneven surface (cobbled pathway).

This information will be used to develop advances in rehabilitation for stroke patients with problems when walking in the community.

Why have I been chosen?

You have been asked to participate in this study because you have been diagnosed with a stroke at least 6 months ago.

Do I have to take part?

It is up to you to decide whether to take part. We will describe the study to you and then go through this information sheet. If you agree to participate we will ask you to give your verbal consent and sign a consent form to show that you have agreed to take part. You are free to withdraw at any time without giving a reason. This will not affect the standard of care you receive.

What will happen to me if I take part?

If you decide to participate, you will be asked to attend the Academic Department of Physiotherapy, King's College London based at London Bridge, London SE1 1UL for a single visit to complete a brief set of questionnaires, two short walking tests in the laboratory, and the outdoor walking test. The brief set of questionnaires will ask about particular symptoms and their severity (for example, feelings of unsteadinessand ability to move), the situations that may produce these symptoms (for example, crowds), emotional state, the ability to perform various daily activities, and confidence in your ability to maintain balance in everyday activities.

The indoor balance tests will look at your normal walking speed and your ability to maintain your balance in standing or while walking during different conditions, such as when the surface is unsteady or when you move your head at the same time.

The outdoor walking test will involve following a set route in the London Bridge area, in the middle of the morning or the afternoon. We would like to gather data by using sensor boxes placed at the small of your back, at the neck level and on the head (hidden in a hat) which are about the size of match box. You will also carry a wireless data logger in a pouch or pocket. You will be followed by two researchers to help you in case you need assistance. You can wear your usual clothing and shoes but please avoid high heels and also please **DO NOT** drink alcohol for 24 hours before the test.

The test can be arranged for a day and session that is convenient for you. Your travel costs will be reimbursed. The total test will take approximately two hours and 30 minutes.

Are there any risks to me from taking part?

You may, on occasions feel unsteady while performing some of the more challenging walking tasks and when undertaking the balance tests. There are risks of falling and risks handling traffic but they should not be greater than the risks you face during your daily activities. You will be closely supervised throughout when performing all tests. If you feel particularly unsteady at any point you can stop the test.

Hypoallergenic adhesive tape will be used to fix the sensor on the skin at the small of your back and on the base of your neck. We will use a spray under the adhesive that will help it to come off easily when the test is finished. There might be some discomfort (similar to taking off sticking plaster) when the sensor comes off but there should be no lasting damage or irritation to the skin. There is also a risk of having an allergic reaction to the adhesive tape. If you have an allergy to adhesives, please inform the staff before the test.

What are the benefits of taking part?

We cannot promise we will be able to help you, but, the extended assessment may help provide further information about the specific balance strategies patients use when walking in challenging outdoor environments. The information from this study will be used to develop an advanced balance and walking rehabilitation programme for people with stroke.

Will my taking part be kept confidential?

All information that is collected about you during the course of this research will be kept strictly confidential. All information for this project will be stored on password-protected computers used only by research staff. Any documents leaving the hospital or testing site will have all personal identifiable information removed.

Will my GP or Medical team know about my participation and results of this investigation?

With your permission we would like to share this information with your referring medical team. Your GP will be informed of your participation in this study.

Will this affect my current treatment?

Participating in this study will not affect your current treatment.

What happens if there is a problem?

This study has been reviewed and accepted by the National Hospital for Neurology and Neurosurgery and Institute of Neurology Joint Ethics Committee. The consultant in charge of this investigation is Dr Doris Eva Bamiou (Consultant in Audiological Medicine, NHNN). Other investigators conducting this study are Dr.MarousaPavlou**and Dr Isaac Sorinola** (Lecturers in Physiotherapy, King's College London), Dr Ruth Mayagoitia-Hill (Lecturer in Assistive Technology, King's College London) Mrs. Marniza Omar (Audiologist, PhD student at King's College London).

If you have any concerns regarding the study please contact Dr MarousaPavlou, the physiotherapist who will be leading the testing and who will try to answer your questions (contact details below). If you are unhappy and wish to complain formally, you can do this through the NHS complaints procedure. Details can be obtained from the hospital.

In the event that something does go wrong and you are harmed during the research and this is due to someone's negligence, then you may have grounds for legal action for compensation against University College London Hospitals NHS Trust, but you may have to pay for legal costs. The normal NHS complaints procedure will still be available to you.

It is up to you to decide whether to take part or not. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect the treatment you receive from your medical or therapy team in any way. You may withdraw your data from the project at any time up until it is transcribed for use in the final report in December 2012.

If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. Your data will be kept anonymously and will not be passed on outside of your medical care team.

Who can I contact for further information?

If you have any queries please contact either Marniza Omar (Audiologist, PhD student at King's College London) or Dr MarousaPavlou, the Physiotherapist leading the testing for this study.

1.Ms. Marniza Omar

Centre of Human & Aerospace Physiological Sciences,

Shepherd's House

Guy's Campus, London

SE1 1UL

Phone: Office: 02078486679; mobile: 07970981127

Email: marniza.omar@kcl.ac.uk

2.DrMarousaPavlou PhD BA MCSP

King's College London

School of Biomedical and Health Sciences

Academic Dept of Physiotherapy

Shepherd's House

Guy's Campus

London

SE1 1UL

Phone: office: 02078486328; mobile: 07834406530

Email: marousa.pavlou@kcl.ac.uk

APPENDIX 17 Consent form (Study 2)

University College London Hospitals NHS

NHS Trust

Centre Number: UCLH Project ID number:

Patient Identification Number for this study: Form version:

CONSENT FORM

Title of project: Study of free walking in patients with stroke

Name of Chief Investigator: Dr. Doris-Eva Bamiou,

Consultant in Audiological Medicine, National Hospital for Neurology and Neurosurgery (University College London NHS trust) and Senior Lecturer, Ear Institute (University College London)

Please initial box

1. I confirm that I have read and understood the information sheet dated …….. (version ……..) for the above study and have had the opportunity to ask questions. ☐

2. I confirm that I have had sufficient time to consider whether or not I want to be included in the study ☐

3. I understand that my participation in this study is voluntary and that I am free to withdraw at any time, without giving any reason, and without my medical care or legal rights being affected. ☐

4. I understand that sections of my medical notes may be looked at by responsible individuals from King's College London, The National Hospital for Neurology and Neurosurgery or from regulatory authorities where it is relevant to my taking part in research. I give permission for these individuals to have access to my records. ☐

5. I agree to take part in the above study. ☐

Centre Number: UCLH Project ID number:

Patient Identification Number for this study: Form version:

CONSENT FORM

Title of project: Study of free walking in patients with stroke

Name of Principal investigator: Dr. Doris-Eva Bamiou,

Consultant in Audiological Medicine, National Hospital for Neurology and Neurosurgery (University College London NHS trust) and Senior Lecturer, Ear Institute (University College London).

Name of patient	Date	Signature

Name of Person taking consent (if different from researcher)	Date	Signature

Researcher (to be contacted if there are any problems)	Date	Signature

Comments or concerns during the study

If you have any comments or concerns you may discuss these with the investigator. If you wish to go further and complain about any aspect of the way you have been approached or treated during the course of the study, you should write or get in touch with the Complaints Manager, UCL hospitals. Please quote the UCLH project number at the top this consent form.

APPENDIX 18 Information sheet (Study 3)

CONFIDENTIAL

Information Sheet

Study Title:Prevalence of illness behaviour in patients with vestibular migraine and vestibular neuritis.

We would like to invite you to take part in a research study in the department of Neuro-otology at the National Hospital for Neurology and Neurosurgery. Please take time to read the following information carefully and discuss it with others (friends, relative and your GP) if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the study

The purpose of this research project is to find out relevant information about patients' experience and attitudes in relation to their symptoms of migraine associated dizziness and inner ear upsets. Previous studies have shown that these factors may influence the way patients react to their balance disorder. Very little is known about how the patients'understanding of their diagnosis affectstheir balance confidence, mobility and daily activities. It is hoped that the outcomes of this study may provide us with useful information to develop better treatments for patients with migraine associated dizziness and inner ear upsets.

Why have I been chosen?

You have been asked to participate in this study because you are between 18-80 years of age and have been diagnosed with either migraine associated dizziness or an inner ear upset. You have been referred by your consultant physician.

Do I have to take part?

It is up to you to decide whether to take part. We will describe the study to you and then go through this information sheet. If you agree to participate we will ask you to give your verbal consent and sign a consent form to show that you have agreed to take part. You are free to withdraw at any time without giving a reason. This will not affect the standard of care you receive.

What will happen to me if I take part?

If you decide to take part you will be given a questionnaire (Illness Behaviour Questionnaire)during your visit to the Neuro-otology department, NHNN. The completion of the questionnaire will not take more than 15 minutes. The questionnaire collects information about your experience and attitudes in relation to your symptoms of migraine associated dizziness and inner ear upsets. We also will ask you to complete Functional Gait Assessment. This test assesses walking ability during different task such as walking over an obstacle or walking with head movements in pitch or yaw. The walking test will take approximately 10 minutes to complete. The whole study will take approximately 30 minutes in addition to your visit time at the neuro-otology department.

What are the possible disadvantages and risks of taking part.

You may, on occasions feel unsteady while performing some of the more challenging walking tasks. However this should not be greater than the risks you face during your daily activities. You will be closely supervised throughout when performing all tests. The procedures themselves do not involve pain or discomfort and there are no risks directly associated with the study. You will be offered breaks between individual testing sessions.

What are the possible benefits of taking part?

There will be no direct benefit for you taking part in this study. However we hope that by conducting this study we will learn more about how patients' with migraine associated dizziness and inner ear balance upsetsview their diagnosis and how this affects their confidence and mobility. This information may help us to improve our treatment strategies in the future.

What will happen to the results of the research study?

The results are likely to be published in a scientific journal but you will not be identifiable in any way. When this study is completed we would like to continue to store your results and to hold the data on our computer. This is because it may be useful to look at the data again in the light of discoveries that may be made in the future. Your medical records will be protected in accordance with the European Data Protection legislationbut you may ask for your personal information to be removed from the database at any time in accordance with the Data Protection Act 1998. Hard copies will be shredded after the storage time is completed.

Can I withdraw from the study?

Your participation in this study is entirely voluntary and you may withdraw at any time without providing an explanation. Your decision will not affect any aspect of your healthcare.

What if there is a problem?

This study has been reviewed and accepted by the**(the information will be filled once it confirm)**Committee. The consultant in charge of this investigation is Dr Rosalyn Davies (Consultant Audio-Vestibular Physician, NHNN). Other investigators conducting this study are Dr.MarousaPavlou (Lecturer in Physiotherapy, King's College London), Dr. Doris-Eva Bamiou (Consultant in Audiovestibular Medicine, NHNN), Mrs. Marniza Omar (Audiologist, PhD student at King's College London) and Mr. Andrew Walker (MSc Student at King's College London).

If you have any concerns regarding the study please contact Dr MarousaPavlou, the physiotherapist who will be leading the testing and who will try to answer your questions (contact details below). If you are unhappy and wish to complain formally, you can do this through the NHS complaints procedure. Details as below:

PALS

Department of Neuro-otology

Box 127

National Hospital for Neurology & Neurosurgery

Queen Square

London WC1N 3BG

In the event that something does go wrong and you are harmed during the research and this is due to someone's negligence, then you may have grounds for legal action for compensation against University College London Hospitals NHS Trust, but you may have to pay for legal costs. The normal NHS complaints procedure will still be available to you.

It is up to you to decide whether to take part or not. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect the treatment you receive from your medical or therapy team in any way.

If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. Your data will be kept anonymously and will not be passed on outside of your medical care team.

Who can I contact for further information?

If you have any queries please contact Dr MarousaPavlou, the Physiotherapist leading the testing for this study.

Dr MarousaPavlou PhD BA MCSP

King's College London

Centre of Human & Aerospace Physiological Sciences,

3.5 Shepherd's House

Guy's Campus

London

SE1 1UL

Phone: office: 02078486328; mobile: 07834406530

Email: marousa.pavlou@kcl.ac.uk

APPENDIX 19 Consent form (Study 3)

University College London Hospitals NHS
NHS Foundation Trust

Department of Neuro-otology

Box 127

National Hospital for Neurology & Neurosurgery

Queen Square

CONFIDENTIAL

Version 2

CONSENT FORM

Title of project: Prevalence of illness behaviour in patients with vestibular migraine and vestibular neuritis

Name of Chief Investigator : MarousaPavlou, Lecturer in Physiotherapy.

Name of person completing the form :

Please tick and initial the box:

1. I confirm that I have read and understood the information sheet for the above study and have had the opportunity to ask questions. ❒

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected. ❒

3. I understand that sections of any of my medical notes may be looked at by responsible individuals from the Neuro-otology Department or from regulatory authorities where it is relevant to my taking part in research. I give permission for these individuals to have access to my records, which will be kept confidential. ❒

4. I understand that my personal details and information about me that is gathered for this research study will be held on a secure, confidential computerised database that is only accessible to the Department of Neuro-otology. This is in accordance with the Data Protection Act 1998. ❒

5. I agree to my GP being informed of my participation in the study. ❒

6. I agree to take part in the study ❒

Continued on next page

Version 2

Patient Identification Number:

UCLH Project ID Number

CONSENT FORM (CONFIDENTIAL)

Title of project: Prevalence of illness behaviour in patients with vestibular migraine and vestibular neuritis

Name of Chief Investigator: MarousaPavlou, Lecturer in Physiotherapy.

_____	_____	_____
Name of subject	Date	Signature
_____	_____	_____
Name of Person taking consent (if different from researcher)	Date	Signature
_____	_____	_____
Researcher (to be contacted if there are any problems)	Date	Signature

Comments or concerns during the study

If you have any comments or concerns you may discuss these with the investigator. If you wish to go further and complain about any aspect of the way you have been approached or treated during the course of the study, you should write or get in touch with the Complaints Manager, UCL hospitals. Please quote the UCLH project number at the top of this consent form.

1 form for Patient
1 to be kept as part of the study documentation,
1 to be kept with the hospital notes